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EVOLUTIONARY SPACE PLATFORM CONCEPT STUDY

VOLUME II – TECHNICAL REPORT
PART B – MANNED SPACE PLATFORM CONCEPTS

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FOREWORD

The Evolutionary Space Platform Concept Study encompassed a 10-month effort to define, evaluate and compare approaches and concepts for evolving unmanned and manned capability platforms beyond the current Space Platform concepts to an evolutionary goal of establishing a permanent-manned presence in space.

The study included three parts:

- Part A - Special emphasis trade studies on the current unmanned SASP concept
- Part B - Assessment of manned platform concepts
- Part C - Utility analysis of a manned space platform for defense-related missions

In Part A, special emphasis trade studies were performed on several design and operational issues which surfaced during the previous SASP Conceptual Design Study (reference: MDC G9246, October 1980) and required additional studies to validate the suggested approach for an evolution of an unmanned platform. Studies conducted included innovative basic concepts, image motion compensation study and platform dynamic analysis.

The major emphasis of the study was in Part B, which investigated and assessed logical, cost-effective steps in the evolution of manned space platforms. Tasks included the analysis of requirements for a manned space platform, identifying alternative concepts, performing system analysis and definition of the concepts, comparing the concepts and performing programmatic analysis for a reference concept.

The Part C study, sponsored by the Air Force Space Division (AFSD), determined the utility of a manned space platform for defense-related missions. Requests for information regarding the results of Part C should be directed to Lt. Lila Humphries, AFSD.

The study results from Parts A and B are reported in these volumes:

- Volume I - Executive Summary
- Volume II - Part A - SASP Special Emphasis Trade Studies
- Volume II - Part B - Manned Space Platform Concepts
- Volume III - Programmatics for Manned Space Platform Concepts

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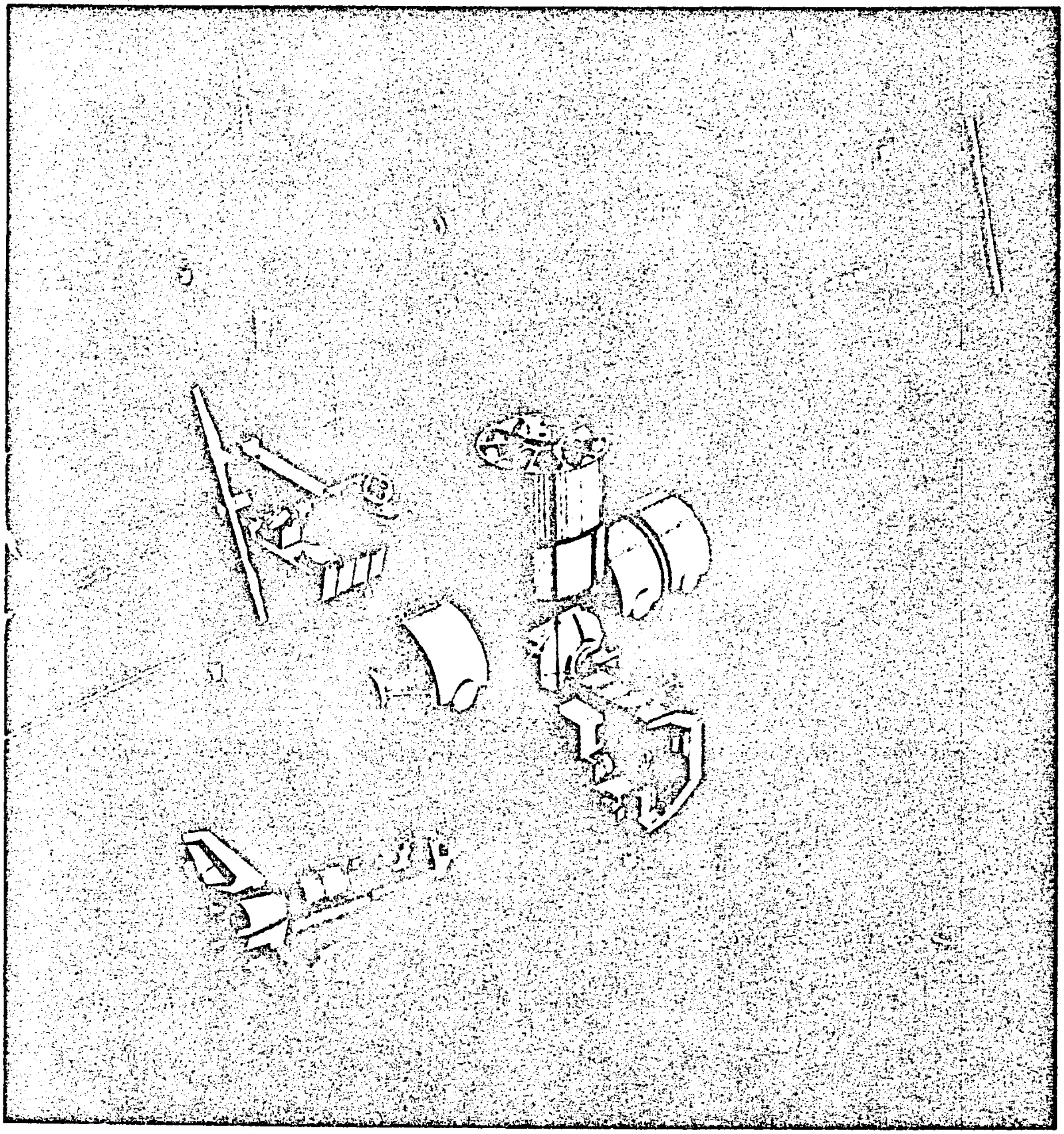

Section 1
INTRODUCTION

The recent launches of the Space Shuttle and the anticipated operation of the Spacelab in the near future are bringing new capabilities to the science and applications communities to accomplish missions in space. These new systems will facilitate the launch, retrieval, refurbishment and reflight of scientific payloads. While the Spacelab sortie mode of operation will continue to be an important tool for the science and applications users, efforts are also in progress to define an approach to provide a simple and cost-effective solution to the problem of long-duration space flight. This approach involves a Space Platform in low earth orbit, which can be tended by the Space Shuttle and which will provide, for extended periods of time, stability, utilities and access for a variety of replaceable payloads.

The program will also be evolutionary in nature. The addition of a pressurized module (which could be derived form Spacelab) to the Space Platform will provide a manned habitated orbital system. This manned space platform (space station) in low earth orbit is seen to be the next major capability needed for the areas of science, applications, technology and commerce. Such a capability offers the ultimate approach to capitalizing on the considerable synergism which is possible when man is used to complement equipment in orbit. The vast potential of this type of capability has been proven in Skylab and will be proven again in Spacelab. Because of the relative short duration of a Spacelab flight, there is also considerable interest among some investigators with manned payloads on Spacelab to reside for longer periods.

Moreover, the manned space platform concept must recognize the realities of budget constraints and payload availability, both of which combine to prescribe a vehicle of modest beginnings and yet flexible for growth into service for those major orbital operations that are emerging. It is apparent that the early manned space platform will support Spacelab-type and derivative payloads. Next, in preparation for later major operations, an interim step of advanced capability development must be accomplished. Finally, with such new

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capabilities, major operations will be implemented to support large structure assembly, orbital transfer vehicle basing and spacecraft servicing. This latter activity is envisioned as feasible by the mid-1990s, if the enabling technology is developed in the early 1990s.

Basically, the technology to provide long-term residence for man in space is in hand and there are now payloads for science, applications and commerce in development which can utilize such a capability. The advanced capability to perform major complex operations must yet be developed and tested in orbit.

The study objective for the Manned Space Platform (Part B) was to define, evaluate and select concepts for establishing a permanently manned presence in space early, with a maximum of existing technology. The study included five tasks: Task B1 - Requirements Analysis for a Manned Space Platform, Task B2 - Concepts Identification, Task B3 - System Analysis and Definition, Task B4 - Comparison of Concepts and Task B5 - Programmatics.

Section 2 of this book describes the results of the systems requirements analysis, including the details of candidate payloads for an early manned space platform. Section 3 describs a number of basic concepts for a manned space platform and an evaluation of their features, benefits and constraints. Section 4 describes the detailed systems analysis and definition performed on two basic concepts recommended in the previous section. Section 5 describes the evaluation approach and recommendation for a reference concept for a manned space platform. Section 6 summarizes the recommended reference concept including a description of the overall configuration, subsystems description and mass summary. Section 7 describes the technology requirements for the early manned space platform.

The appendices provide a list of references (Appendix A), a list of the acronyms and abbreviations used in this report (Appendix B) and the Design Guidelines and Criteria Document (Appendix C) prepared under the system requirements task.

Study results and recommendations must be evaluated and compared within the context of the fundamental guidelines and the major assumptions used in

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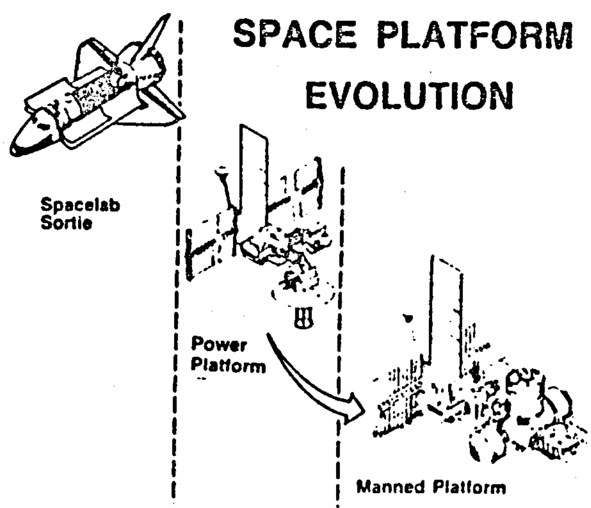
performing the analyses and/or developing the conceptual designs. Therefore, to provide such a frame of reference for the material to be discussed, the original study guidelines are summarized as follows:

- The Space Shuttle shall be considered as the earth launch vehicles and the Space Shuttle User's Handbook shall be used to provide the associated guidelines.
- The Space Platform shall be used as the basic resources module for the manned space platform concept.
- Maximum utilization of existing hardware, technology, experience and facilities is desired.

This study, therefore, addressed the feasibility of an evolutionary space system which would cost-effectively support long-duration manned payloads using a Space Platform which provides centralized basic subsystems as a sequel to the Shuttle-Spacelab sortie (seven-day) flight of manned payloads as shown in Figure 1-1.

Figure 1-1



The objectives of the study in brief are listed in Figure 1-2 and the key program considerations in Figure 1-3.

Figure 1-2

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STUDY OBJECTIVES

Define, Evaluate, and Select Concepts for Evolving:

- **A Space Station in Conjunction with the Space Platform for NASA Science, Applications and Technology**
- **A Permanently Manned Presence in Space Early, with a Maximum of Existing Technology**

Figure 1-3

VFO798

KEY PROGRAM CONSIDERATIONS

- **Foundation of Realistic Payloads**
- **Conservative Budget Assumptions**
- **Goals for Initial Capability**
- **Goals for Capability Growth Steps**
- **Capabilities of Power System**
- **Extent of Existing Equipment Use**
- **Revisit/Resupply Logistics Scope**
- **Safety and Contingency Management**
- **Involvement and Impacts of Participants Other Than NASA**

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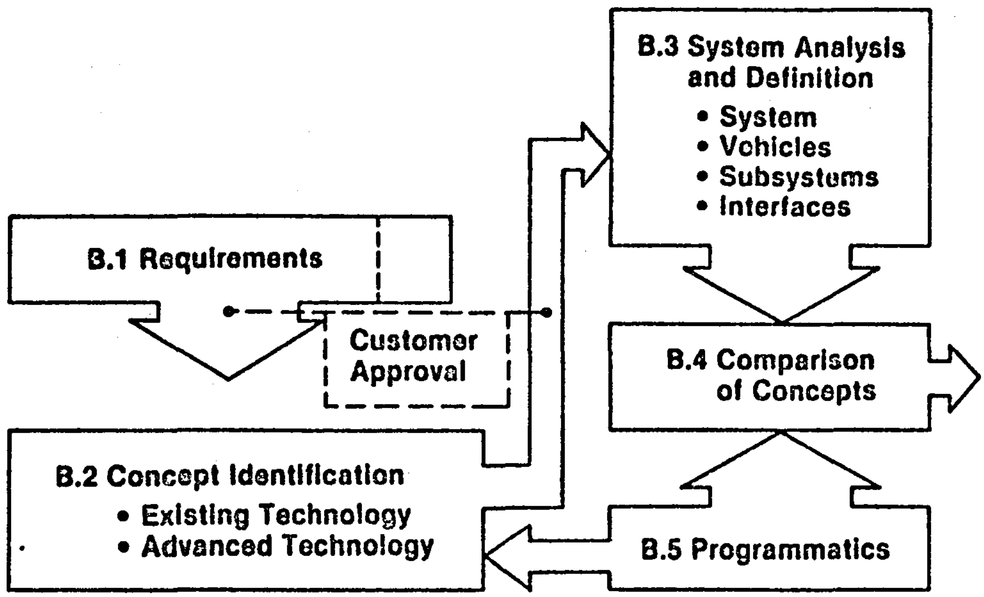
The study was performed in classic Phase A fashion as illustrated in the study flow depicted in Figure 1-4. Note again, only Subtasks B.1, B.2, B.3 and B.4 are reported in this Volume II B, whereas Subtask B.5, Programmatics, is documented in Volume III.

Figure 1-4

TASK B — MANNED PLATFORM CONCEPT



The conclusions of the study are outlined briefly in Figure 1-5. It is important here to note that the concept embodies an initial step of some conservatism.

This approach was based on the results of the payload survey, which indicated a group of users which could well be served by two to four people envisioned as the crew of an early 1990s station. However, the valid prospects of much more extensive operations in the late 1990s called for a concept which could be modularly expanded to serve first of all the prepatory technology development needs and then finally the actual major operations.

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Figure 1-5

STUDY CONCLUSIONS

- **Manned Space Platform ($250K Study)**

Payloads	
• Initial Phase (First 2 Years)	Modest Size Group for Science and Applications (Loads of 2-4 Pallets + 1-2 Spacelabs)
• Mid-Phase (3rd-5th Years)	More of the Above Plus Technology Demonstrations for Advanced Capabilities
• Ultimate Phase (5th Year On)	Large Structure Buildup, OTV Basing and Spacecraft Servicing
Program Scope	Modest Initially With Growth Flexibility; Slaved to Firm Manned and Unmanned Program Needs
Vehicles	
• Modest Beginning and Growth Indicated	Initial Crew of Two Growing to Four (Central Module Payload Module Logistics Modules — Habitat Modules Exterior OP's. Module)
Technology	
• Vehicle	Modified Spacelab Satisfies Habitat and Payload Module Needs
• Subsystems	Much Existing; Some Adaption Required
• Advanced Capabilities	Much to Be Done; Demonstrations for Ultimate Operational Phase

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Section 2
SYSTEM REQUIREMENTS (TASK B.1)

Introduction

The broad program objectives for the manned platform are listed in Figure 2-1. The approach to this task, as dictated by the contract Statement of Work, considered the following:

- manned safety criteria
- maximum use of existing hardware
- evolutionary growth
- currently identifiable/projected mission requirements

Because of the preliminary nature of definition of the last of the aforementioned items, the preliminary design developed initially considered mainly the first three items. The mission requirements were identified/projected as a result of an extensive survey conducted as the study progressed. This meant

Figure 2-1

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BROAD PROGRAM OBJECTIVES
— MANNED PLATFORM —

- **New Low-Earth-Orbit Capability**
  - — Long-Duration Manned Presence With Periodic Shuttle Visits
- **Schedule, Initial and Future Capabilities**
  - — 1989: Selected Science, Applications and Technology Payloads
  - — 1995: Growth to Support Major Operational Missions On-Site and In Remote Orbits
- **Relationship to Other Capabilities**
  - — Complement to Unmanned Spacecraft and Short Duration Spacelab
- **Support Systems**
  - — Shuttle and Space Platform
- **Technology Approach**
  - — Existing Hardware Wherever Cost-Effective

that a general, early capability system (primarily and R&D-type facility) was initially conceived using existing (or assumed to be existing) hardware--Shuttle, Spacelab and Power System to be specific.

The R&D nature of the facility conceived, as it turns out, was quite appropriate in view of the R&D nature of the mixture of candidate payloads that was identified as the study progressed. However, the requirement for growth into later capability for "larger, longer duration science/applications and space operations" was assured by the incorporation of numerous features for modular exchange or growth at the subsystem and vehicle levels.

Moreover, the initial incremental capability of the system developed was purposely prescribed to be conservative, i.e., a crew of two to four, to capitalize on Skylab, Shuttle and Spacelab experience and to keep initial costs low. Such conservatism is appropriate since it is clear that the manned platform would fulfill the needs of one segment of the total payload community "pie" as shown in Figures 2-2A and 2-2B. Other payload carriers (Unmanned-Dedicated spacecraft, the Unmanned-Multi-user spacecraft and Short-Duration

Figure 2-2A

ROLE OF MANNED PLATFORM IN PAYLOAD CARRIER FLEET

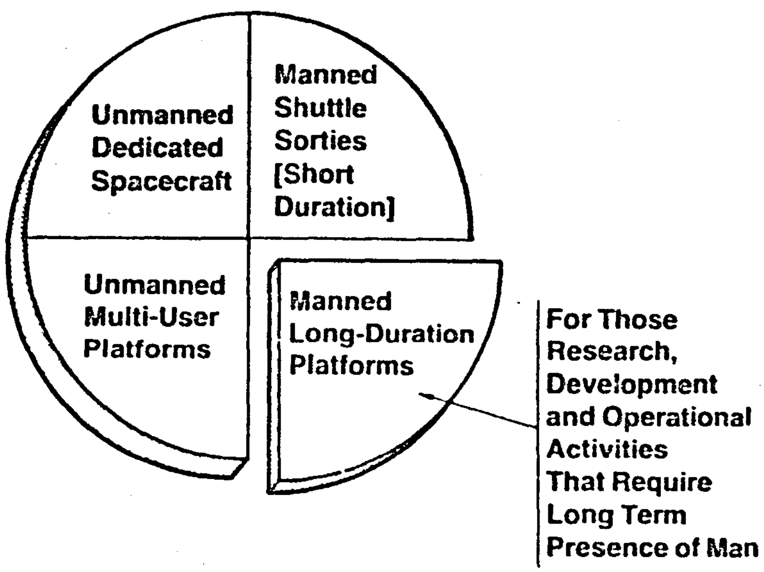

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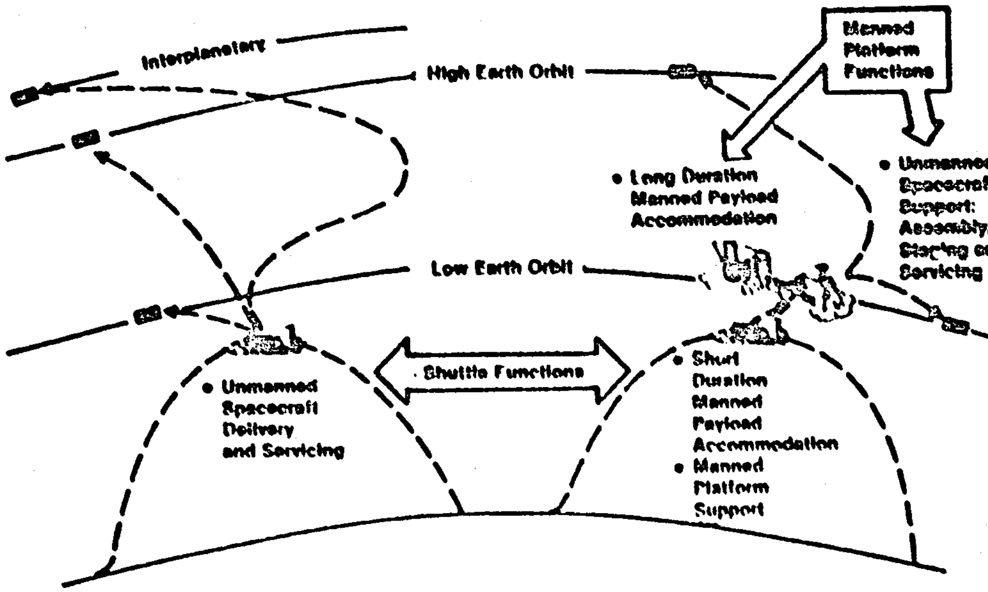
Figure 2-2B

FUTURE SPACE ACTIVITIES VIA SHUTTLE



Shuttle will continue to fulfill the needs of many payloads which have either no requirement for man in orbit at all or are satisfied with the seven-day Shuttle flights. Recognizing this, our early concepts for the manned platform began conservatively and were kept so even moreso by presumed funding constraints. This conservatism in approach was manifested first of all in the considerable use of hardware elements from Shuttle, Spacelab and even Skylab, since with some adaption modifications, they could be used to considerable and good advantage. Again, for later growth, the early elements of the system were fashioned to permit easy, modular additions.

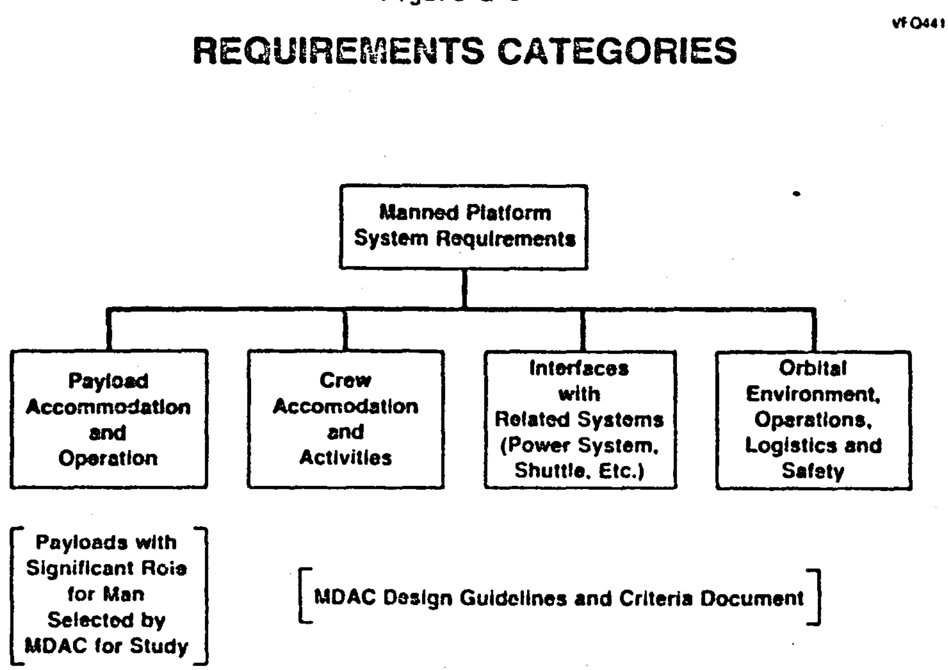
The need for such growth, it was concluded, remained to be prescribed by some study which would analyze and define the character of large space operations, most probably, it appears, in the areas of large structure construction, upper stage basing and spacecraft servicing.

Thus, the manned platform developed in this study was based on system requirements that embodied conservatism, low-cost and maximum-use of existing equipment, all aimed at an early capability but with growth potential.

There are four general categories of requirements which make up the totality of manned platform system requirements, as shown in Figure 2-3. Since there was no specific set of payloads prescribed for the study, the definition of payload accommodation and operation requirements were developed as the study progressed. However, basic provisions for numerous interior and exterior payloads were incorporated into the basic concept.

The remaining three requirements categories were covered in a special document prepared early in the study, entitled MDAC Design Guidelines and Criteria, published as Appendix C to this final report. This 52-page document was compiled by reviewing the requirements prescribed in Shuttle, Spacelab, Skylab and all of our past space station studies. It was reviewed by NASA/MSFC, modified as to their comments and republished. These categories pertain primarily to the sustenance and effective daily routines of the crew, interfaces with those systems that would support this new system in the 1990s and, the many impacts of operating, supporting and assuring reliability and safety in the orbital mode.

Figure 2-3



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This subtask (B.1) introduces and feeds into the related study subtasks as shown in Figure 2-4. The contents of this section are as follows: Subsection 2.1 identifies the types and phasing in prospect for payloads in general. Subsection 2.2 outlines the basic and growth objectives envisioned for the manned space platform configuration. Subsection 2.3 addresses fundamental crew accommodation assumptions, whereas 2.4 defines the source of the Space Platform used as a reference design. Subsection 2.5 highlights the overall requirements for accommodating payloads, crew and vehicles in the unique environment of space and 2.6 defines the MDAC background that constitutes the fourndation for the System Design Guidelines drafted for and used in this study and presented in Appendix C.

2.1 PAYLOAD REQUIREMENTS/GENERAL (details in 2.7)

Since there is not as yet any specific mission model or set of payloads planned for a manned platform, out study began with a survey of potential payload candidates. This survey concluded that there were four basic areas of need emerging for a space station, namely, (1) longer-duration reflight of those manned-involvement payloads which will fly on short-duration Shuttle/Spacelab flights (2) new innovative payloads which will signficantly benefit from manned involvement and (3) technology demonstration payloads preparing for future missions which would benefit from support from a manned-base for assembly, staging or servicing and finally (4) payloads for the actual conduct of such advanced missions (see Figure 2.1-1).

Specifically, the survey identified payload activities in three phases, as shown in Figure 2.1-2. The evolution of activities would therefore, with selected examples, develop as shown in Figure 2.1-3. The schedule phasing of such an activity as cryo stage technology and later OTV operations is shown in Figure 2.1-4, integrated with a representative mix of other payloads. Note that only certain science and applications disciplines are represented in this list. Numerous other science payloads will be satisfied with short-term manned flights on Shuttle/Spacelab or do not need direct in situ manned involvement at all and thus will fly an unmanned spacecraft.

Figure 2-4

TASK B — MANNED PLATFORM CONCEPT

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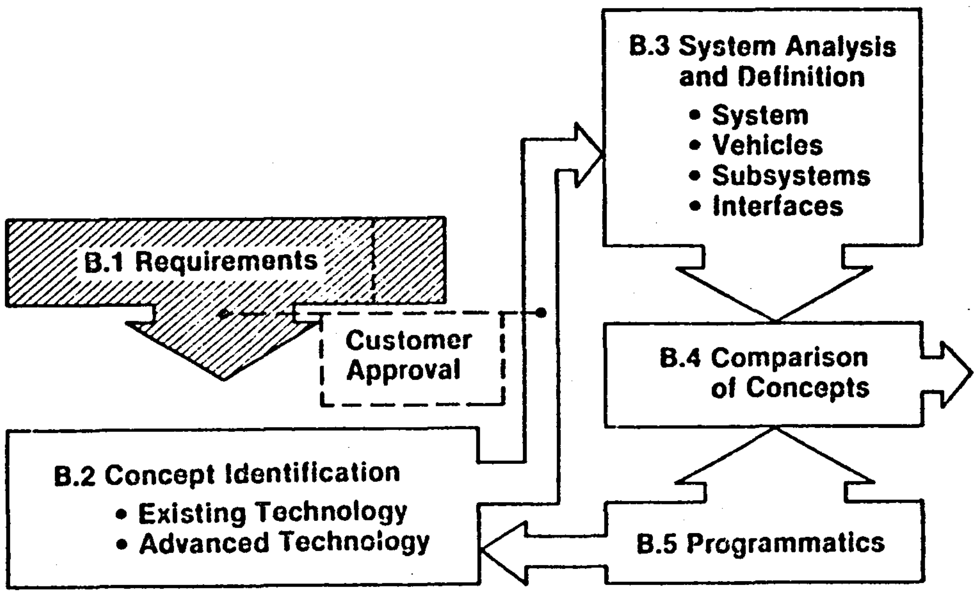

Figure 2.1-1

EMERGING NEEDS FOR A MANNED PLATFORM

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Longer Flight for Certain Shuttle/Spacelab Payloads

- **The Number of Manned Sortie Payloads Is Growing and Many Will Benefit Substantially From Subsequent Flights of Much Longer Duration**

New, Innovative Uses of Man

- **Many Science, Applications and Commercial Project Plans Include Major Use of Man in Orbital Residence**

Laboratory for Advanced Hardware and Techniques

- **Many Future Space Missions will Be Large Scale and Require Advance Capability Developments Which Must be Pre-Tested for Long Periods With Man in Orbit to Evaluate Performance**

Extensive Crew-Use in Large Scale Mission Support

- **Many Weeks of Space Resident Crew Activity Will Be Required to Setup and Checkout Planned Spacecraft With Large Reflectors, Orbital Transfer Vehicles and Periodic Servicing**

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Figure 2.1-2

MANNED PLATFORM PAYLOADS

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Performance of On-Site Missions
- Solar-Terrestrial Science
- Oceanography
- Materials Processing (Pharmaceutical Experiments)
- Life Science

Performance of Advanced Capability Testing
- Propellant Storage/Handling
- Large Structures
- Remote Control Servicing
- Environmental Controls
- Sensors and Pointing Systems
- EVA Techniques and Accessories
- Unmanned Vehicle Maneuvering/Docking
- Pharmaceutical Pilot Plant

Early Years

Operational Support for Remote Missions
- GEO-Mission Staging
- Large Payload Setup/Alignment
- Spacecraft Recovery and Servicing
- Subsatellites and Targets
- Pharmaceutical Production Plant

Later Years

Figure 2.1-3

EVOLUTION OF MANNED PLATFORM ACTIVITIES

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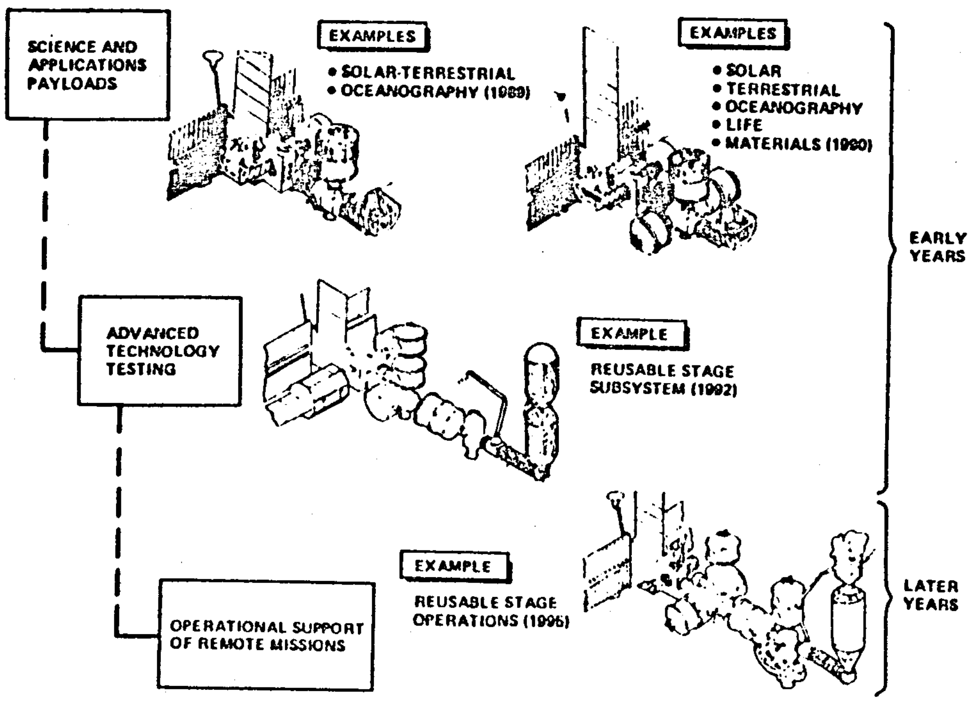

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Figure 2.1-4
MANNED SPACE PLATFORM UTILIZATION (CANDIDATE PLAN)

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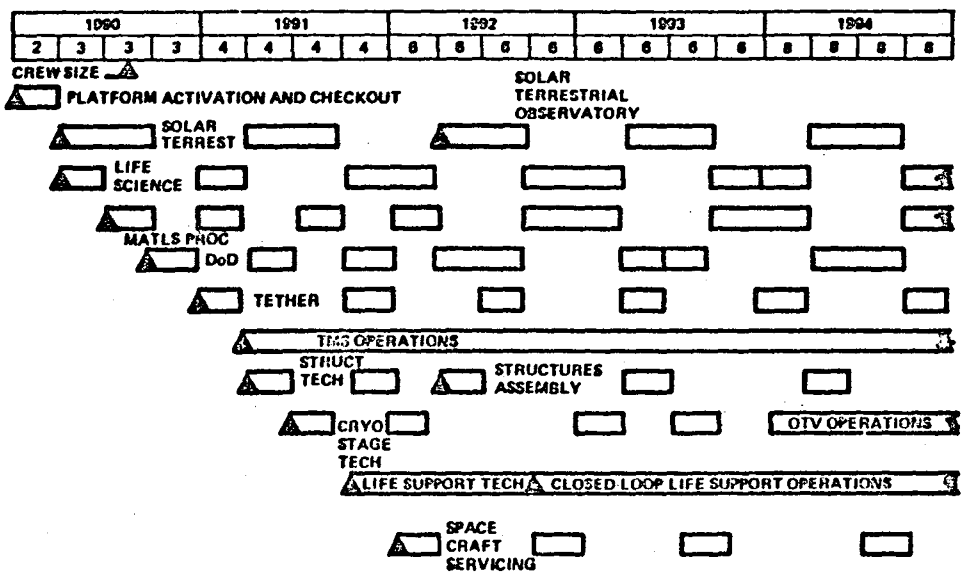

In order to assure a reasonably-substantial set of potential users for the early manned platform being conceived, the payloads selected were only those which now had active NASA sponsorship, either in study or development activity. Figure 2.1-5 lists such payloads with the sponsoring organizations.

Many of the payloads selected are not as yet defined in terms of a configuration and operational mode for a manned space platform (MSP). Therefore, descriptions were developed in this study for each payload (covered in Paragraph 2.7 to varying depths using available information or in-house expertise) so that appropriate categorical configuration-driver accommodations would be incorporated into the MSP concept.

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Figure 2.1-5

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REPRESENTATIVE PAYLOADS REQUIRING MANNED SUPPORT ON ORBIT

■ Solar Terrestrial	— Soft X-Ray, SEPAC, AEPI, WISP (GSFC and MSFC)
■ Oceanography	— Synthetic Aperture Radar (JPL)
■ Life Sciences	— Research Animal-Holding Facility (Ames) — Biomedical Test Equipment (JSC)
■ Materials Processing	— Pharmaceutical Pilot Plant (MDAC) — MEC (MSFC)
■ Technology for Advanced Capabilities	— 10-30m Deployable Reflector (Ames and JPL) — Deployable Beams and Antennas (MSFC and JPL) — ECLSS (MSFC, JSC, Ames) — Propellant Storage and Transfer (LRC) — Teleoperator Maneuvering System (MSFC)
■ Advanced Capabilities	— Large Structure Buildup (MSFC/JPL/JSC) — Spacecraft Servicing (MSFC and GSFC) — Orbital Transfer Vehicle Basing (MSFC)

The Space Platform in its 12.5 kW, 25 kW and greater growth versions can more than accommodate the payloads identified in this study. Specifically, our concept for a basic, earliest MSP is one with possibly only two men, two exterior pallet payloads and a few internal rack payloads, certainly within the capacity of the 12.5 kW Space Platform. Next, the concept for an expanded MSP adds more interior payloads and an exterior technology demonstration payload, or two, easily accommodated by the 25 kW version of the Space Platform. Ultimately, when major materials manufacturing plans may be added, some 50 kW growth version of the Space Platform would be needed.

Since the Space Platform was being designed to flexibly accommodate a vast array of manned and unmanned payloads, there was no additional analysis conducted to define detailed payload requirements for power, thermal control, communications or data. Rather, the effort focused on internal and external configuration accommodations for the paylods and their operations plus the distribution systems within the manned platform for the subsystem resources obtained from the Space Platform. Figure 2.1-6 illustrates the initial listing of major accommodations required by the payloads defined for and basic operation of the MSP. Note the extensive requirements for exterior

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Figure 2.1-6

MANNED PLATFORM ACTIVITIES/ACCOMMODATION REQUIREMENTS

VFO356

		ACCOMMODATION REQUIREMENTS					
		INTERIOR CONTROLS	INT P/L MTG	EXT PORT/ EXIT	EXT OPS BEAM	AUX RMS	TELE-OPER
PERFORMANCE OF MISSIONS ON-SITE	• SOLAR-TERRESTRIAL SCIENCE	√		√	√		√
	• OCEANOGRAPHY	√		√			
	• LIFE SCIENCE	√	√	√			
	• MANUFACTURING APPLICATIONS (PHARMACEUTICALS)	√	√	√			
TESTING FOR ADVANCED CAPABILITIES	• REMOTE CONTROL OPERATIONS	√			√	√	√
	• PROPELLANT STORAGE/HANDLING	√		√	√	√	
	• LARGE STRUCTURES	√		√	√	√	
	• ENVIRONMENTAL CONTROLS	√			√		
	• SENSORS AND POINTING SYSTEMS	√	√	√	√		
	• EVA TECHNIQUES AND ACCESSORIES	√		√	√		
	• RENDEZVOUS AND DOCKING	√		√	√	√	√
	• PHARMACEUTICAL PILOT PLT.	√	√*	√	√	√	√
SUPPORT FOR REMOTE MISSIONS	• GEO MISSION STAGING	√		√	√	√	√
	• SUBSATELLITES AND TARGETS	√		√	√	√	√
	• LARGE PAYLOAD SETUP	√		√	√	√	√
	• SPACECRAFT SERVICING	√		√	√	√	√
	• PH. RMACEUTICAL PROD. PLT.	√	√*	√	√	√	√
STATION OPERATION	• CONTROLS/INSTRUMENTATION/ DATA HDLG	√					
	• CREW AND RELATED EQUIPMENT (IVA/EVA)	√	√	√			
LOGISTICS	• CREW AND PAYLOAD SUSTENANCE AND EXCHANGE	√		√		√	√

* SEPARATE FREE FLYER

functions and thus major configuration drivers. Figure 2.1-7 gives specific examples of equipment inherent in some representative payload and MSP operation functions.

2.2 PLATFORM REQUIREMENTS

In view of the high potential of a restricted budget funding for any new NASA system of the 80s, a requirement for an evolutionary capability MSP was assumed. That is, the system was to begin with an early elemental capability and have an adaptability for modular growth to progressively greater capability. The basic steps in the evolution became clear as it was found that the earliest payloads would most likely not be operationally challenging but merely longer flight duration versions of the type flow in Spacelab sortie flights on Shuttle (internal rack and exterior pallet payloads). Thus, the early manned space platform would merely replace the Shuttle as a payload carrier and provide a greater capability for (1) long-term crew residence, (2) approximately one Spacelab load of internal payloads, (3) exterior berths

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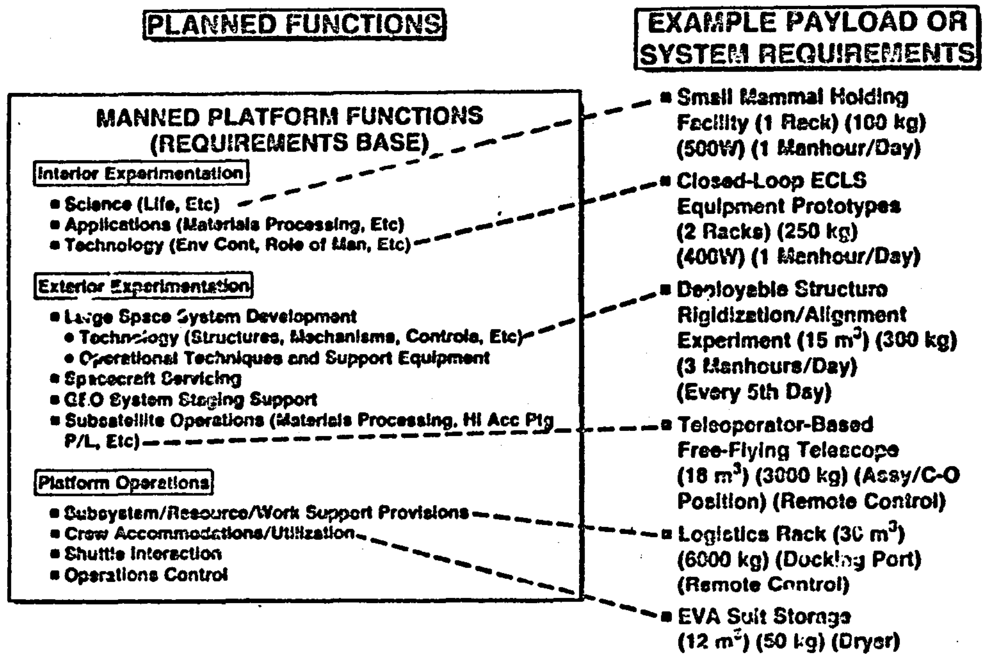
Figure 2.1-7 VFJ531N

FUNCTION-DRIVEN REQUIREMENTS



for two to three palletized payloads for viewing/sensing or materials processing, (4) periodic logistics and (5) Orbiter interfaces. This capability would probably be adequate for the first or even second year of operation.

Since more ambitious objectives are envisioned for the MSP in the mid-to-late 1990s (such as large structure assembly, orbital transfer vehicle basing and spacecraft servicing), the next step in the MSP evolution would be a capability to support the development of equipment and techniques to perform these eventual major operations. This capability would need to be available in probably the third to fifth years of the MSP operations. Finally, the ultimate phase would be the extensive capability required to perform (rather than prepare for) the major operations previously mentioned, namely, large structure assembly, orbital transfer vehicle basing and spacecraft servicing. This latter, ultimate capability would probably be made available in the sixth year of the MSP operation.

These top-level views of the type of evolutionary services planned for the MSP constitute the system philosophy for the basic modularization of the vehicle.

2.3 CREW REQUIREMENTS

The MSP must of course accommodate the various needs of crew access to the inside of pressurized MSP modules from the ascent vehicle (the Shuttle), controls for operational management of the platform, provisions for breathing, eating, sleeping, hygiene support, protection from natural environment, IVA and EVA access within and around the vehicle and, most importantly, emergency protection in one isolated section of the pressurized volumes. Many of these functions call conceptually for some sort of basic central module, sort of a mini-station to start with, build upon and to retreat into if necessary. Such a basic module mini-space station in effect, would most probably be the first unit attached to the Space Platform delivered by, and mostly filling a prior Shuttle flight. With growth in mind, such a unit should also have numerous ports for access to pressurized modules which are added later.

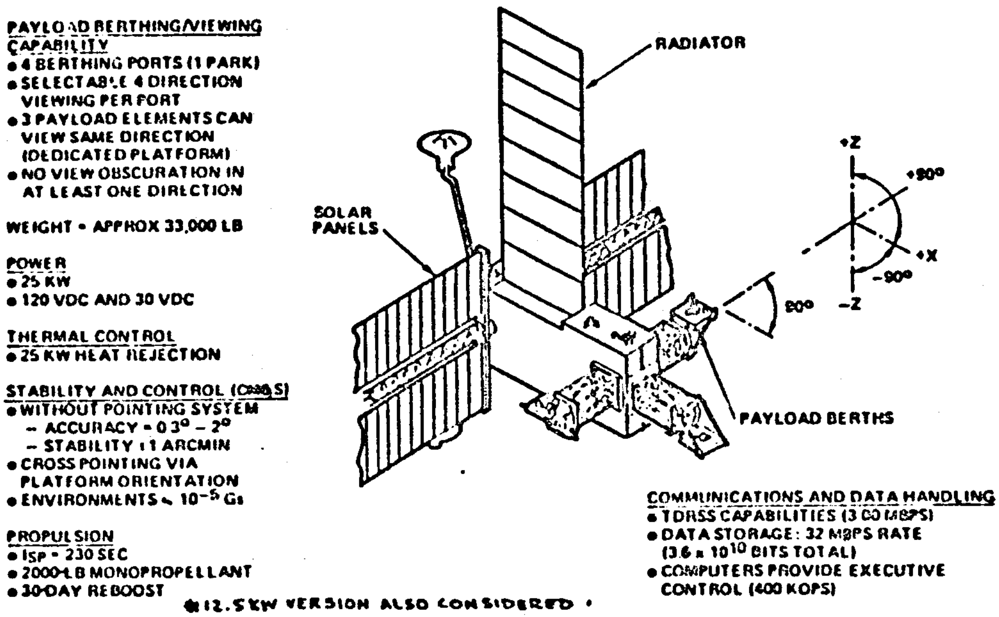
2.4 INTERFACES WITH RELATED SYSTEMS

Certain requirements are imposed (on the concept developed for the manned platform) by the systems with which it will operationally interface. In this case, the Space Platform is specified as the subsystem resource and or course, the Shuttle is to provide initial delivery and subsequent periodic logistics revisits.

The design of the Space Platform used in the study is that defined in the NASA/MSFC Reference Concept documented in their PM-001, dated September 1979 (see Figure 2.4-1). This data was supplemented by a memo from the Space Platform Project Office at MSFC specifying 12.5 and 25 kW power levels, added 120 VDC provisions, 300 Mbps KSA link return, better pointing available on the 12.5 kW version plus updated weights and lengths. Throughout the development of the concept details of Space Platform physical and organic interfaces will be shown to influence the design of the attached manned platform.

In like manner the size and shape of the Shuttle cargo bay, the reach capability of the remote manipulator system, crew access to docked vehicles, etc., will be seen to impact the concept developed for the manned platform.

Figure 2.4-1
REFERENCE SPACE PLATFORM (MSFC 1979)



Volume XIV of the Shuttle Systems Documentation series is used as a basic guide in this area.

2.5 ORBITAL OPERATIONS AND ENVIRONMENT

The physical and operational characteristics of the payloads, all of the vehicles which end up in various assemblage in orbit at different times, as well as the natural and induced environments attendant to such operations in low earth orbit, all will be shown to constitute requirements for overall shaping, modular distribution/congregation or directionality of buildup of the manned platform.

2.6 POTENTIAL SOURCES FOR APPLICABLE HARDWARE

In keeping with the early activation and low-cost objectives of the study, the use of hardware elements from existing manned systems was to be evaluated. The systems primarily considered were Shuttle/Orbiter, Spacelab and Skylab.

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2.7 DETAILS OF CANDIDATE PAYLOADS

As mentioned earlier (in 2.1, Payload Requirements/General) the payloads which are considered as candidates for the MSP constitute a unique mix which varies in content through the years of platform life, roughly as follows:

Early Years (1989-95)

- Science and Applications Payloads
- Technology Demonstration Payloads for Advanced Missions

Later Years (1995-?)

- Advanced versions of above payloads, plus,
- Advanced missions such as buildup of large structure payloads, basing of orbital transfer vehicles and spacecraft servicing

In the remainder of this subseciton, details of various candidate payloads are presented as used in the study for developing manned platform concepts in later tasks. The payload candidates included are presented in a time-related order, as follows:

Early Years

- Solar-terrestrial (Paragraph 2.7.1)
- Oceanography (Paragraph 2.7.2)
- Electrophoresis Drug Production (Paragraph 2.7.3)
- Life Sciences (Paragraph 2.7.4)
  - Biomedical
  - Biology

Mid-years (more of the above plus the following)

- Rendezvous Sensor and Control Development Tests (Paragraph 2.7.5)
- Environmental Control and Life Support Development Tests (Paragraph 2.7.6)
- Deployable Structure Technology (Paragraph 2.7.7)
- Propellant Handling Technology (Paragraph 2.7.8)
- EVA and Remotely Controlled Servicing Technology (Paragraph 2.7.9)

Later Years

- Large Multi-mirror Reflector Assembly Alignment (Paragraph 2.7.10)
- Orbital Transfer Vehicle Basing (Paragraph 2.7.11)
- Servicing Retrievable Spacecraft (Paragraph 2.7.12)

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Detailed information on the above listed payloads has been gathered from a multiplicity of sponsoring organizations in NASA and scientific groups. Each has specific interest in the prospect of flight of their payload of interest on the MSP, or buildup, OTV support or servicing on the same platform.

Although all of the candidate payloads are of equal interest and importance, more detailed treatment has been given in this study to Life Science, Large Structures and OTV Basing by capitalizing on particular experience and related effort at MDAC. Obviously much more treatment of each payload candidate is required, however, study funds were not available for such broader depth of treatment.

It is NASA/MSFC's plan to fund selected efforts in 1982 on payload and mission prospects for the manned platform.

2.7.1 Solar-terrestrial Research

A number of experiments in the area of solar-terrestrial research are currently planned for conduct onboard Spacelab missions. Although involved scientists are excited about the prospects of such experiments and eagerly anticipate the results, they readily admit that the use of the Spacelab as a solar-terrestrial research facility has certain deficiencies that could be remedied by the use of a manned space platform.

Figure 2.7.1-1 illustrates some of the capability differences between Spacelab and a manned platform. The first row addresses differences in mission duration (seven days vs 90 days); the second row addresses payload capacity; the third, the number and direction of onboard sensors; the fourth, the use of free-flyers; the fifth, the number and training of onboard scientists and the last, direct access to and interaction with onboard data and control functions. Each of these capability differences has an important influence on the compexity and refinement of the potential experiments.

The use of a manned space platform has been stressed as opposed to an unmanned SASP. Scientists working in solar-terrestrial research are in general agreement regarding the value of a trained onboard observer. Figure 2.7.1-2 illustrates some of the advantages that man can provide. It has already been

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Figure 2.7.1-1

COMPARISON OF SPACELAB AND MSP CAPABILITIES IN SOLAR-TERRESTRIAL STUDIES

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SOLAR-TERRESTRIAL EXPERIMENT REQUIREMENTS	SPACELAB MISSION LIMITATIONS	MSP CAPABILITIES
MONITOR SOLAR FLUX OVER SEVERAL SOLAR CYCLES (27-DAY ROTATIONS)	MISSION LIMITED TO A MAXIMUM OF 7 DAYS	SAMSP MISSION DURATION PROLONGED WITH 90-DAY CREW ROTATION
ACCOMMODATE SUFFICIENT INSTRUMENTATION TO MAKE SIMULTANEOUS OBSERVATIONS OF SELECTED SOLAR FEATURES, ATMOSPHERIC DYNAMICS, AND MAGNETOSPHERIC VARIATIONS	PAYLOAD CAPACITY LIMITED TO LAUNCH WEIGHTS OF 65,000 LB (MAX)	PAYLOAD CAPACITY ESSENTIALLY UNRESTRICTED – ADDITIONAL COMPONENTS INCORPORATED WITH SUBSEQUENT LAUNCHES
MONITOR CHANGES IN ATMOSPHERE CHARACTERISTICS SIMULTANEOUS WITH SOLAR FLARES AND SUBSTORMS	SENSOR POINTING RELATIVELY FIXED AND UNIDIRECTIONAL	MULTIPLE SENSORS WITH CAPABILITY OF MONITORING TARGETS-OF-OPPORTUNITY SIMULTANEOUSLY IN SOLAR DISC, ATMOSPHERE AND MAGNETOSPHERE
MONITOR MAGNETOSPHERIC EVENTS WITHOUT ELECTROMAGNETIC CONTAMINATION FORM SPACECRAFT	CANNOT ACCOMMODATE NUMEROUS REMOTE SENSORS CONNECTED TO, OR FLYING NEAR, SPACELAB	PERMITS USE OF NUMEROUS TETHERED SENSORS AND ASSOCIATED FREE FLYERS
COMPARE REAL-TIME DATA FROM SOLAR, ATMOSPHERIC, AND MAGNETOSPHERIC SENSORS AND DECIDE ON APPROPRIATE TARGETS AND OBSERVATION MODES	MAXIMUM OF SINGLE SCIENTIST IN SMALL SPACELAB, CREW-LIMITED INTERDISCIPLINARY KNOWLEDGE	LARGER NUMBER OF ONBOARD SCIENTISTS ENHANCES VALIDITY OF INTERDISCIPLINARY DECISIONS
PROVIDE INSTRUMENTS TO PERFORM ENVIRONMENTAL PERTURBATIONS TO INVESTIGATE ENERGY COUPLING MECHANISMS	ALTHOUGH SHUTTLE/SPACELAB CAN CARRY AND SUPPORT THE LARGE RESOURCE AND SUPPORT REQUIREMENTS THE ABILITY TO PERFORM THESE CONTROLLED ACTIVE EXPERIMENTS UNDER VARYING ENVIRONMENTAL CONDITIONS IS ESSENTIAL	WITH MULTIPLE CREW ROTATIONS INVESTIGATIONS CAN BE EXPANDED TO SOLAR CYCLE DURATIONS AND GREATER

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Figure 2.7.1-2
**ROLE OF
MAN WITH ORBITAL SENSORS**

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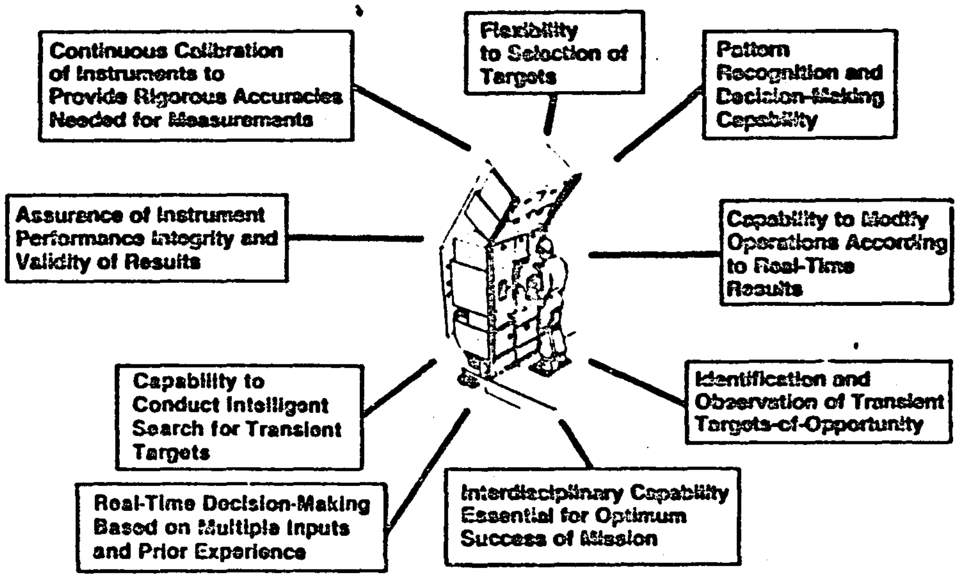

pointed out on the previous chart that not only is a trained observer an advantage, but one or more trained scientists that may be available on later space platforms would greatly enhance both the flexibility of the experiment and the validity of the results.

The vital role of man with sensors in orbit was highlighted in the "NASA Workshop on Solar-terrestrial Studies from a Manned Space Station" (February 1977, Utah State University). Excerpts from the conference paper are presented here.

> "Beginning with Skylab, scientists were able to carry out coordinated multi-instrument observations of the sun, with the onboard scientist-astronaut able to key the observations to transient solar events.
>
> "(On the manned platform) correlation monitors will provide onboard scientists with full-disk, modest spatial resolution information for the purposes of interplanetary and terrestrial correlations.

"The high-instrument accuracies will require continued calibration which can be carried out by the onboard science staff.

"We foresee that some of the monitor-type experiments and, to an even larger degree, most of the research-type experiments will not be executed with the required performance to solve the problem in question without the intervention of a trained observer in the space station. The painstaking calibration and measurement accuracy needed for the solar-irradiance determination and the high pointing accuracy required for the small-scale magnetic field observations are but two examples that indicate the necessity for manned intervention in well-planned observing sequences. With the sophisticated instrumentation we have proposed, other needs are highly likely to occur. These needs may include repair activities or the flexibility for observing complex phenomena--examples in which the Skylab experience demonstrated the desirability of man's presence.

"The major limitation of Spacelab-based observations appears to be related to the limited flight duration.

"Further, it seems likely that a highly trained specialist would, in the course of a three-month mission, gain competence and scientific insight through continued handling of new scientific data even more than a specialist located on the ground.

"An important aspect of a manned involvement is maintaining the integrity of instrument performance and absolute calibration necessary to detect secular trends in the composition of the atmosphere due to pollutants.

"Of all the aspects of an STO, the solar-weather objectives are most interdisciplinary and demand the greatest real-time, innovative reaction by the staff of the Observatory. The very nature of these objectives asks for recognition of relationships between members of a complex sequence of events stretching from the sun to the surface of the earth. The ensemble of instruments and data displays on the STO will allow the

Observatory scientists to focus on specific relationships and to follow them as they unfold and evolve. Complete automation to follow these varied relationships seems virtually impossible. Further, the real-time pattern recognition and correlative capabilities of the human mind may catch significant relations that could easily elude notice during subsequent processing of recorded data at a ground site.

"Through the use of these solar situation monitors, the onboard science staff will be able to maximize the scientific return by selecting and pointing specific instruments in the solar cluster for tailored observation of the particular phenomenon taking place.

"A main theme through the whole discussion was the man-in-the-loop notion, strongly endorsed by all four subgroups. It was argued that the inclusion of man in situ often may be of decisive importance, as in a coronal transient phenomenon or the sudden development of a tropical hurricane."

2.7.1.1 Candidate Activities on an Early Manned Space Platform

Mentioned in the previous section was the fact that a number of solar-terrestrial experiments are planned and are currently being developed for conduct on Spacelab. It is anticipated that these same experiments will be repeated the early manned platform. The equipment items used on Spacelab flights will be installed on the platform supplemented with a few additional items that will allow the greater payload capacity and research flexibility of the platform to enhance the experimental procedures and increase the value of their results.

In this case, specialists at NASA/MSFC defined for this study the experiments and related equipment that will be considered for the early manned platform. These were: active cavity radiometer (ACR), solar ultrviolet spectral irradiance monitor (SUSIM), soft x-ray telescope, space experiments with particle acceleration (SEPAC), recoverable plasma diagnostic package (RPDP), atmospheric emission photometric imaging (AEPI), waves in space plasma (WISP), Imaging Spectrometric Observatory (ISO), magnetospheric multiprobes (MMP) and high resolution doppler imager (HRDI). The recommended location of these experiments on the manned platform is shown in Figure 2.7.1.1-1, a conceptual drawing of the platform.

Not all of the defined experiments will require the detailed involvement of man in their operation. Note in Figure 2.7.1.1-2 that the ARC, SUSIM and RPDP (located on the pallet) are fully automatic and have no controls within the manned module. Other experiments, such as the soft x-ray telescope, AEPI and WISP involve man primarily in target selection and pointing control with some role, also, in data monitoring. Still others, such as SEPAC, are heavily dependent on man's involvement.

It should be noted that even though an experiment, designed for location on the Spacelab pallet, requires little or no crew involvement, it does not mean that the experiment coulnd't be redesigned to utilize man's unique capabilities, thus enhancing the experiment. Figure 2.7.1.1-3, derived from Skylab experience, clearly demonstrates the vital roles that crew activities played in a solar experiment. This experiment, designed for crew involvement, would necessarily have been less successful if designed solely for automatic operation.

Figure 2.7.1.1-1

MANNED PLATFORM — SOLAR/ TERRESTRIAL PAYLOAD CANDIDATES

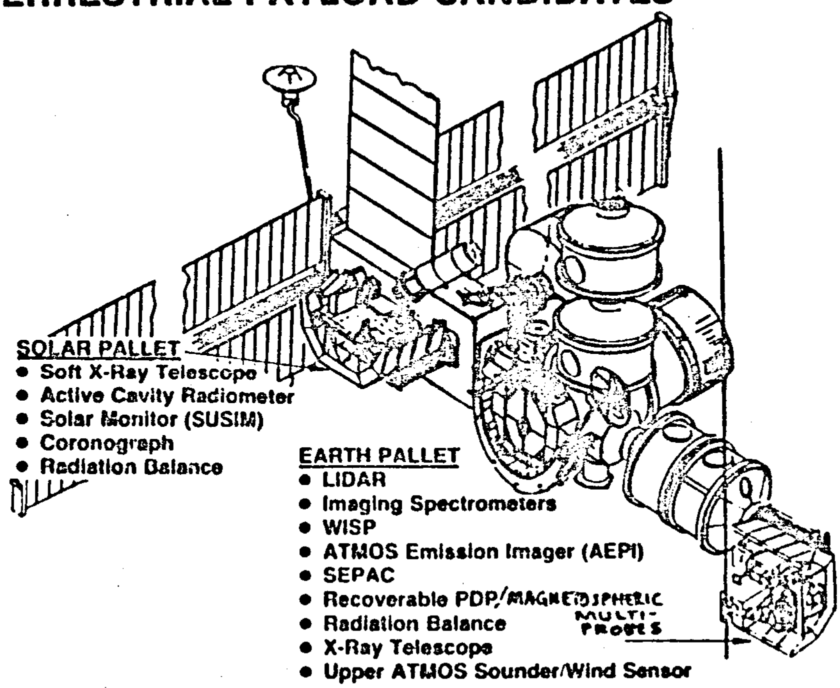

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Figure 2.7.1.1-2

EARLY SOLAR-TERRESTRIAL PAYLOAD CONTROLS FOR MANNED PLATFORM

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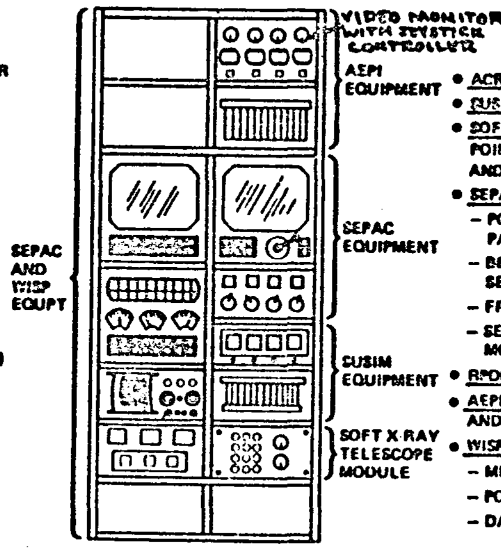
SOLAR EXPERIMENTS

- ACTIVE CAVITY RADIOMETER (ACR) (PALLET ONLY)
- SOLAR ULTRAVIOLET SPECTRAL IRRADIANCE MONITOR (SUSIM)
- SOFT X-RAY TELESCOPE

TERRESTRIAL AND MAGNETOSPHERIC EXPERIMENTS

- SPACE EXPERIMENTS WITH PARTICLE ACCELERATION (SEPAC)
- RECOVERAL PLASMA DIAGNOSTIC PACKAGE (RPDP) (PALLET ONLY)
- ATMOSPHERIC EMISSION PHOTOMETRIC IMAGING (AEPI)
- WAVES IN SPACE PLASMA (WISP)



CREW ACTIVITIES

- ACR – NONE
- SUSIM – NONE
- SOFT X-RAY TELESCOPE – POINTING AREA SELECTION AND DATA MONITORING
- SEPAC
  - POINTING CONTROL OF PARTICLE ACCELERATOR
  - BEAM CHARACTERISTIC SELECTION
  - FREE-FLYER CONTROL
  - SENSOR AND DATA MONITORING
- RPDP – NONE
- AEPI – TARGET SELECTION AND POINTING CONTROL
- WISP
  - MEASUREMENT INITIATION
  - POINTING CONTROL
  - DATA MONITORING

Figure 2.7.1.1-3

HIGH-VALUE CONTRIBUTION OF ON-ORBIT CREW WITH IMAGING PAYLOADS

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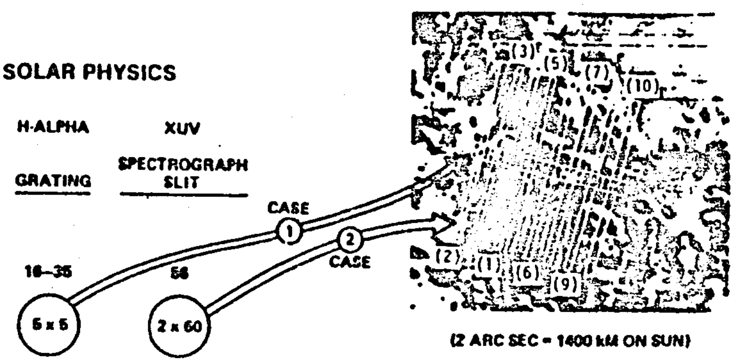
EXAMPLE DISCIPLINE SOLAR PHYSICS

SELECTED EXPERIMENTS



FIELD OF VIEW ARC MIN

SPOT VIEW ARC SEC

(2 ARC SEC = 1400 kM ON SUN)

BASIC ROLES OF CREW

- EXECUTE EXPERIMENT MODE SEQUENCES AND MONITOR IMAGES
- INTERPRET/CORRELATE PHENOMENA (VIDEO, DIGITAL, AND AUDIO FLARE ALARM INPUTS)
- CONTROL FINE POINTING IN REAL TIME PER INTEREST

CASE 1

- MANUALLY SCAN GRATING BACK AND FORTH ACROSS H-ALPHA EMISSION POINTS AND WATCH XUV DETECTOR TO LOCATE AND POINT AT SPOTS OF PEAK EMISSIONS

CASE 2

- STEP 2 x 60 ARC MIN SLIT ACROSS IMAGE IN 2- TO 5-ARC MIN STEPS CHROMOSPHERIC NETWORK CELLS DIFFICULT TO RECOGNIZE (DARK AND BUSHY CLUMPS) (10 ARC SEC BOUNDARIES)
- CREW SELECTS PROMINENT, NOT DISSIPATING CELL
- ZOOM VIEW SO THAT EYE CAN AVERAGE OUT IRREGULARITIES
- POINT AT CELL BOUNDARY AND ZOOM WITHOUT LOSING LOCATION
- CREW ENHANCES POSSIBILITY OF CATCHING FLARE ONSET AND CORONAL TRANSIENTS WHICH OFTEN FOLLOW FLARES

CONTINGENCY ROLL OF CREW

- PLAN SCHEDULE AND RESCHEDULE IN REAL TIME (PRIMARY, SECONDARY, NEW INTERESTS)

Figures 2.7.1.1-4 and -5 present timelines for an early manned platform where on and in solar terrestrial and life science payloads are accommodated.

2.7.2 Oceanography

As one of the more recently emphasized disciplines of space science and applications, the program for orbital observation in oceanography is in an emerging state of objective formulation and data acquisition. NASA/JPL, Scripps Institute of Oceanography and the Office of Naval Research are actively engaged in related planning. The Navy project NEREUS plan is discussed later in this section as an example of the opportunities foreseen in this important new space discipline. The broad interests of oceanography, the significant potential role of man and past experiences on Skylab and Columbia are shown in Figure 2.7.2-1.

The one-time Seasat provided some outstanding data, but, due to its premature demise much was left unachieved. The recent flight of a Synthetic Aperture Radar (SAR) on the second flight of Columbia in the OSTA 1 payload package

Figure 2.7.1.1-4

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EXPERIMENT ACTIVITY TIMELINES

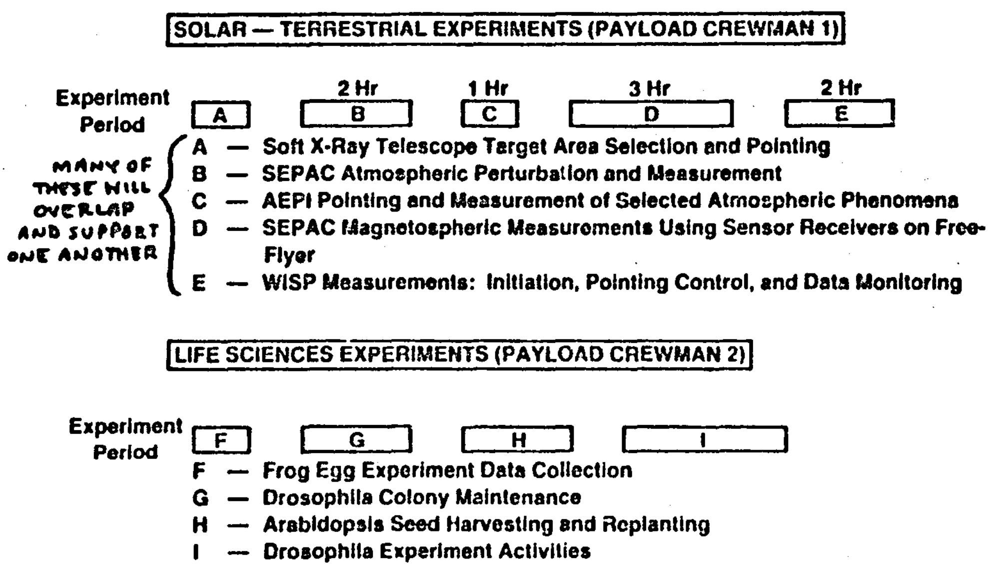

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Figure 2.7.1.1-5

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CREW TIMELINE — 3 CREWMEN
TYPICAL MISSION DAY

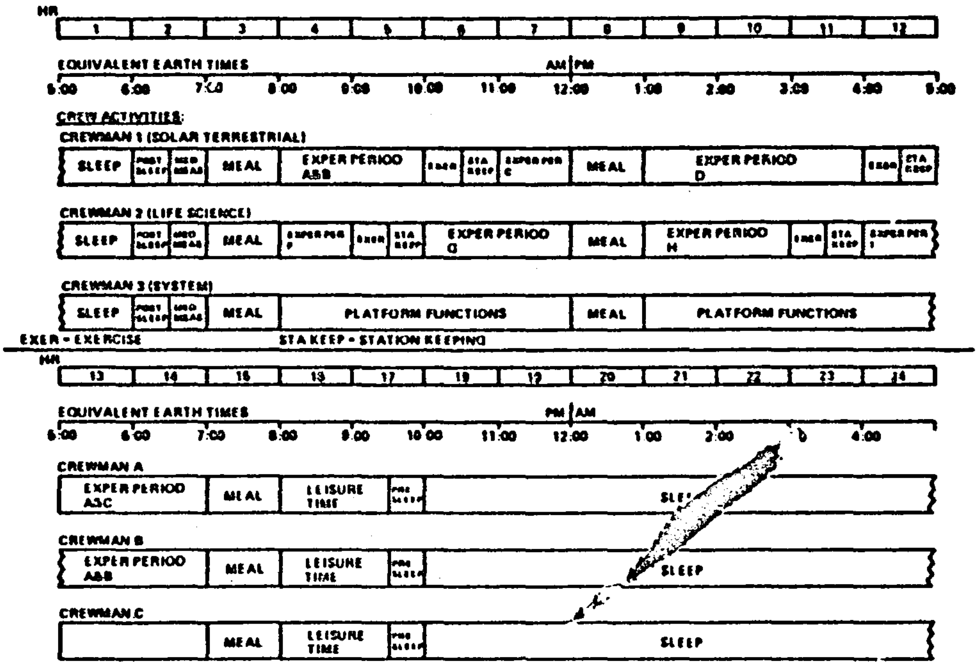

Figure 2.7.2-1

VFO365

ROLE OF MAN IN OCEANOGRAPHIC SCIENCE/APPLICATIONS FROM SPACE

Areas of Interest

- Resources (Fish, Biota, Minerals)
- Location of Phenomena
- Fluctuation of States
- Tracking and Prediction

Capabilities Required

- Trained Observers
- Synthetic Aperture Radar and Hasselblad Camera
- Truth Site Coordination
- Computer/Graphics

Role of Man

- Directing Observations Based on Multiple Inputs/Experiences and Viewing Eddies, Slicks With Sun Glitter, Etc

Skylab

- Crew Observations and Photos Contributed to New Awareness of Mesoscale Phenomena; Stimulated Truth Site Verification

Columbia

- Crew Observations, Synthetic Aperture Radar and Hasselblad Photos Provide Spectacular New Findings on Surface and Subsurface Phenomena "obtained interesting sea state data caused by wind or currents." In addition, much land coverage. Oceanographic principal investigators specifically look forward to the use of man for extended periods with orbiting sensors for a number of reasons, namely:

- Since detailed oceanographic viewing from orbit for science and applications is in an infant state, there are often surprises in the data. Often such situations point out the need for capabilities or flexibilities that whre not designed into the instrument package because of a lack of knowledge of what "might be seen" from orbit. Designing broad capabilities into an instrument, including modular modifications on orbit with manned involvement would provide a very valuable resource, not to mention contingency repairs which could have possibly saved the early failure of the Seasat mission.

- The routine periodic access to space offered by the Manned Space Platform increases the prospects of sequential investigations consistent with a reasonable "career time scale."

- The Manned Space Platform would provide a valuable test facility for the development test and refinement of sensors to be later used in an unmanned mode when the phenomenology of oceanographics is better understood.

- Science progress will be greater per unit of time with man-in-the-loop in orbit because of the ability to reach in real-time in response to numberous inputs (including visual sighting) to quickly repeat or modify the experimental activity.

The SAR flown recently on Columbia II is of particular interest to the oceanographic community (see Figure 2.7.2-2 for information on capabilities and role of man). For example, SAR data registered surface effects of sea mounts and objects well below 100 to 1000 feet below the surface. There is still conjecture as to what the surface effects really are and how they relate to whatever underwater stimulus, thus creating an intense new area for research. The broad field of eddy currents, their nature, their persistence, their scope

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Figure 2.7.2-2

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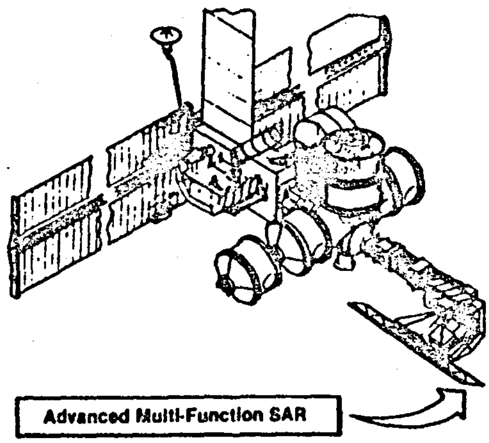
EARTH-ORIENTED SYNTHETIC APERTURE RADAR ON MANNED PLATFORM



Wavelengths: L- to K_u-Bands
Polarization Combinations: HH, VV, and Cross
Resolution: 10m to 300m
Swaths: 100 Km to 500 Km
Incidence Angles: 15° to 60°
Calibration:
  Amplitude: 2 dB Accuracy, 1 dB Precision (1σ Variation)
  Spatial: 10m to 300m Accuracy (1σ Variation)

Areas of Interest

- Geologic, Mineral, Petroleum — Exploration
- Geological Structure Mapping
- ★ Oceanographic State Dynamics
- Fish Location
- Biota Concentration
- Agriculture and Forestry
- Ice Distribution

★ **Role of Man**

- Scheduling Based on Visual Observation of Target and Radar Images
- Truth Site Coordination
- Multi-Input Correlation

and influence on internal or surrounding ocean structures can be aided significantly by the SAR.

Even more intriguing is the importance attached by oceanographers to the visual and hand-held photographic coverage available when men are in orbit to cover the significant number of variations anticipated in ocean viewing and to supplement and calibrate automated sensor coverage.

In his project NEREUS Plan (see references), Dr. Robert Stevenson of the Office of Naval Research/Scripps Institute of Oceanography indicates that:

> "A revolution took place in physical oceanography in the mid-1970s. Whereas for nearly 100 years oceanographers had looked at the oceans as large, mildly turbulent bodies of water bounded by huge, majestically flowing current systems, improved means of measuring showed the ocean to be turbulent at all scales and at all frequencies. Furthermore, and most important, it became clear in the mid-1970s that the major portion of the ocean's kinetic energy (as much as 99%, in one estimate) is confined to

mesoscale eddies with diameters on the order of 100-300 km and frequencies from days to a few tens of days! Although there are certain ocean areas where eddies are more concentrated than others, there are no parts of the ocean without some mesoscale turbulent features.

"Because of the size, frequency and worldwide distribution of the eddies, there is no possibility of studying the dynamics of these systems by conventional, seagoing techniques. The only reasonable method is by remote sensing from space.

"The recognition of eddies from space came at about the same time as the oceanographers' revelation of mesoscale ocean dynamics. The work during Skylab was most significant in this regard. Cold-core eddies in the northwest Caribbean Sea were photographed from Skylab 2, July 1973. In January 1974, while Skylab was still in orbit, a P-3 Navy patrol plane from Weather Reconnaissance Squadron Four, based at Naval Air Station, Jacksonville, Florida, dropped air-expendable bathythermographs along the spacecraft's track in the Caribbean. Cold cores of water extended up to the sea surface in a distribution similar to that in the space photographs.

"The existence of what then seemed to be regularly organized eddies along a current boundary, and which followed well the laboratory findings of Roshko stimulated the thoughts of their influence on acoustics in the upper ocean.

"Oceanographic and acoustic studies in the ANZUS EDDY Project in the Tasman Sea off Australia were sufficient to verify that such eddies do have a significant effect on underwater acoustic propagation. Direct arrival propagation loss measurements in the eddy duct clearly showed the effect of eddy structure on received energy levels. This duct, solely a result of the eddy, responded as an acoustic waveguide with optimum propagation at 100 Hz.

"If eddies were restricted to coastal waters, the tactical situation would be less difficult than it is. Eddies exist throughout the world's oceans, however. If the eddies were static features, from season to season and year to year, the effects on acoustics could be predicted and tactics planned accordingly. Research by ONR investigators in the Pacific Ocean has shown us, however, that not only do the eddy streams vary, they may even disappear, unpredictable.

"It is clear that our understanding of the physical details of upper ocean eddies is as unknown as their life histories. Concentric rings, internal waves normal to and parallel with their boundaries, and shear zones have all been observed in the synthetic aperture radar imagery from Seasat.

"Truly useful data have been obtained from satellites. Real advances in our understnading of the ocean have been made. There is much remaining to be learned, however, and the "learning curve" will be very shallow without the definitive experimental capability Shuttle provides. It simply means that scientists, whether 20 ro 70 years old, can carry aboard a variety of "breadboard" sensors <u>that need not be space hardened</u>. The mix of frequencies, look angles, data rates, and sensor sequences can be so arranged to meet the situation at hand, in the same way that experiments are conducted in a laboratory on earth. We can conduct, in a word, <u>research</u>.

"In early December 1968, the Science and Technology Advisory Committee to the National Aeronautics and Space Administration met in La Jolla, California, to consider the application of manned spaceflight to scientific and technology objectives in the 1975-1985 decade. The results of the committee's discussions were published in two volumes in 1969 and noted, as a basic theme, that the benefits to the nation dictated that the United States remain in the forefront of all major categories of space activity, in particular, manned spaceflight capability.

"In their recommendations, they noted that high priority should be given to (1) the extension of long-duration manned spaceflight capability in earth orbit, (2) achievement of low-cost, manned, space transportation systems such as Space Shuttle, (3) a long-duration, manned space station as the logical step toward (4) placing manned observatories in earth orbit

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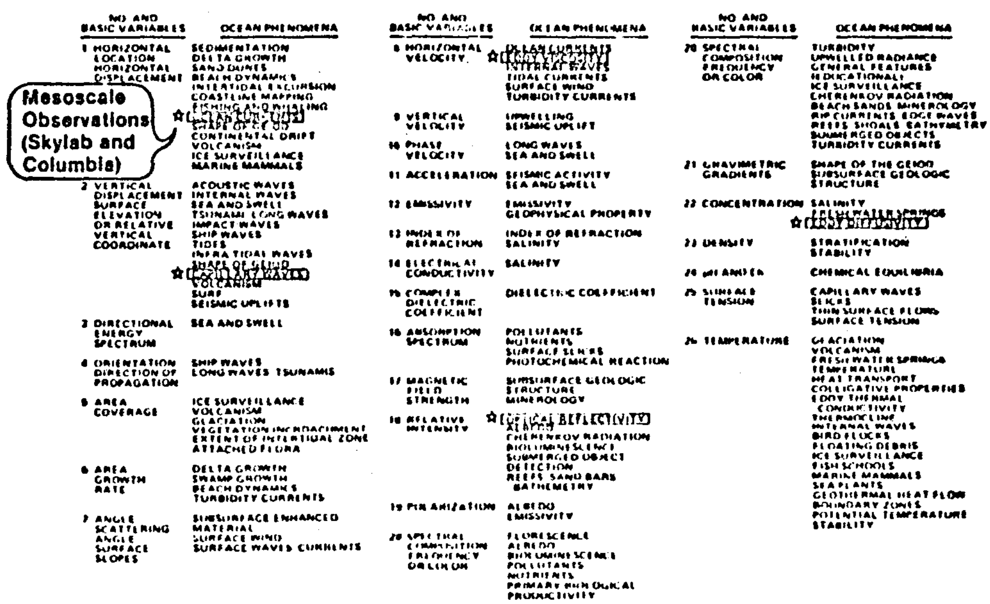
in which all scientific and technological practices would benefit by the attendance of specialists.

"The entire report and the recommendations by the Advisory Committee were visionary, but well within state of the art and funding capabilities of NASA and the other United States agencies who would, by interest and mission, benefit from an earth-orbiting complex of observatories. Agencies such as the Department of Defense, National Oceanic and Atmospheric Agency and the Department of Interior readily come to mind. But, a multitude of local governmental groups and private industries can be quickly identified as well."

Figure 2.7.2-3 lists the basic oceanic variables and phenomena of interest to investigators and highlights the broad ocean current and detailed eddy current interests of currently great interest. Note the areas of contribution from Skylab and Columbia flights.

Figure 2.7.2-3
BASIC OCEANIC VARIABLES AND PHENOMENA

VFQ368



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More specifically, Figure 2.7.2-4 defines the observables, sensory modes and sensor characteristics associated with eddy currents in particular and Figure 2.7.2-5 indicates those instruments which would be useful in the sensing of such eddy current phenomena.

2.7.3 Biological Processing (Electrophoresis Drug Production)

The term biological, or pharmaceutical, applies to a large number of substances used in medicine which include antibiotics, vaccines, enzymes and hormones--all produced by activities of living cells. These cells may vary from single-cell organisms such as bacteria or fungi to specialized cells from complex organisms including humans and other mammals. For the purposes of this discussion, however, products will be limited to those produced by mammalian cells.

In the process of manufacturing a biological, pertinent cell types are first isolated from other types residing in the same tissue or organ. Separation is normally accomplished by electrophoresis. The cells are then concentrated and cultured in a growth medium to increase their number. At some predetermined

Figure 2.7.2-4

OCEAN — SHAPE OR DISPLACEMENT MEASUREMENTS (FREE SURFACE)**

VFO367

OCEAN PHENOMENA	BASIC VARIABLES OF INTEREST	PHENOMENA SCALE SPACE	PHENOMENA SCALE TIME	OBSERVABLE	SENSORY SYSTEM MODE	SENSING INSTRUMENTS AND/OR METHODOLOGY	BANDWIDTH AND FREQUENCY RANGE	RADIATION TYPE SENSED	POINTING ACCURACY (RADIANS)
WAVES SEA AND SWELL	SFC ELEV RELATIVE VERTICAL COORDINATE SFC SLOPE	1m	1 SEC	BACKSCATTER EMITTED FROM SURFACE OF VARIABLE ROUGHNESS	PASSIVE	MICROWAVE RADIOMETRY WITH VARIABLE ANGLES ORTHOGONAL POLARIZATION DIFFERENTIAL	20 40 KMC	INCOHERENT	MOVABLE DECLINATION
	SFC ELEV RELATIVE VERTICAL COORDINATE	1m	1 SEC	LOSS OF SPECULAR RETURN AT NORMAL INCIDENCE, BACKSCATTER FROM ILLUMINATED ROUGH SURFACE	ACTIVE, SHORT PULSES AT DISCRETE FREQUENCY STEPS	RADIOMETRY WITH CM RADAR VERTICALLY ORIENTATED, ALTIMETRY/ SCATTEROMETRY	10 100 MC	COHERENT	10^{-2}
	SFC ELEV RELATIVE VERTICAL COORDINATE	1m	1 SEC	MEAN RISE TIME OF BACKSCATTERED SIGNAL OF A NO OF SHORT PULSES TO PERMIT DISCRIMINATION BETWEEN MEAN ELEV OF TROUGHS AND MEAN ELEV OF WAVE CRESTS	PULSED ACTIVE NANOSECOND PULSES	SCATTEROMETRY GATED CM RADAR WITH FREQUENCY CODED OR PHASE MODULATED PULSES	1000 MC	INCOHERENT	10^{-2}
		1m	1 SEC	LASAR ALTIMETER TO YIELD SURFACE PROFILE	FM CW ACTIVE	CONTINUOUS ALTIMETRY VERTICALLY ORIENTED	VISIBLE NEAR VISIBLE, 0.3-0.9μ BANDWIDTH 100 MC	COHERENT	$\cdot 10^{-3}$
WAVES CAPILLARY	SFC ELEV SFC SLOPE	1 cm	0.1 SEC	BACKSCATTER AND REFLECTED GLITTER PATTERNS OF THE SUN'S IMAGE	PASSIVE	RADAR/ SCATTEROMETRY HIGH RESOLUTION TELESCOPIC PHOTOGRAPHY	VISIBLE	INCOHERENT	$\cdot 10^{-2}$

Eddy Current Interests

*MDAC STUDY FOR NASA MSFC/JSC (NAS8 21064)

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Figure 2.7.2-5

OCEANOGRAPHY INSTRUMENT/ PARAMETER MEASUREMENT LIST

VFO366

INSTRUMENT DESCRIPTION	NUMBER OF PARAMETER MEASUREMENTS SATISFIED	INSTRUMENT DESCRIPTION	NUMBER OF PARAMETER MEASUREMENTS SATISFIED
DAY/NIGHT CAMERA	11	WATER-WAVE MICROWAVE SPECTROMETER	1
SYNOPTIC MULTIBAND CAMERA	7	IR INTERFEROMETER SPECTROMETER	3
12-IN. FL METRIC CAMERA	2	SCANNING UV, VISIBLE, IR ABSORPTION SPECTROMETER	6
24-IN. FL PANORAMIC CAMERA	2	8.0-GC RADAR ALTIMETER SCATTEROMETER	4
SPIN-SCAN CAMERA SYSTEM	1	HIGH-RESOLUTION RADAR IMAGER	6
ADVANCE VIDICON CAMERA	4	STAR TRACKER	1
PASSIVE MICROWAVE STEREOSCOPIC IMAGER	1	GRAVITY GRADIOMETER	1
HIGH-RESOLUTION IR RADIOMETER	1	MAGNETOMETER	1
MEDIUM-RESOLUTION IR RADIOMETER	1	IRLS	5
MICROWAVE RADIOMETER	7	UHF-SFERICS RECEIVER	0
		LANGMUIR PROBE	0
		PULSED LASER	1
		UV PHOTOMETER	0
		PYRHELIOMETER	0
		POLARIMETER	3

Instruments for Eddy Current Diagnosis Supplemented by Crew Observations

Similar to Shuttle Imaging Radar (Second FI/OSTA Payload Group)

time, the cells are transferred to a production medium which enhances the production of the biological. Cells are removed and the biological, invariably protein in nature, is then separated from the medium and from other byproducts of cell metabolism. The biological is, finally, further purified and preserved.

It has been hypothesized that the weightlessness of spaceflight will considerably enhance the manufacturing process, increasing both the purity and yield of the biological. The process of electrophoresis, which will be used both in the initial cell isolation and in the separation of the biological from the production mediums, is adversely afffected by convection currents produced by thermal gradients in the fluids and by separation of the sample from the carrier fluid because of density differences, when the process is conducted in terrestrial laboratories. Since both adverse effects are gravity dependent, the separation is expected to be more complete and the throughput significantly increased when the process is conducted in space. In addition, techniques are available for cell culture which take advantage of the continuous suspension of the elements, significantly increasing the rate of cell production.

Despite the advantages offered by space, establishing a production plant on a space vehicle is an expensive and difficult undertaking. The resulting product, therefore, must be carefully selected to warrant the output of money and effort. Figure 2.7.3-1 identifies some of the products that are current candidates for production in space. All are medically valuable; all are produced only in small, expensive quantities in terrestrial laboratories; and the production process of each should benefit from weightlessness.

2.7.3.1 The Role of Man in Biological Processing

It was earlier stated that the production process of a biological in space involves a number of subprocesses, each an important contributor to the final product. In the development of a space production facility, it is expected that each subprocess (e.g., electrophoretic separation, cell culture, biological production, biological separation) is expected to be the subject of

Figure 2.7.3-1

PRODUCTS BEING INVESTIGATED FOR BIOLOGICAL PROCESSSING IN SPACE

VFP933

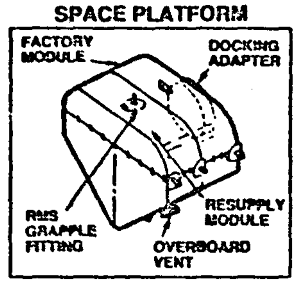
Proteins and Polypeptides

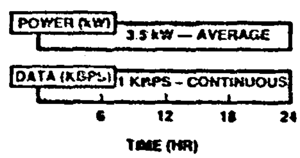
- **Enzymes**
  - Urokinase (Dissolves Blood Clots)
  - Antihemophilic Factor VIII (Controls Bleeding)
  - Alpha -1- Antitrypsin (Treatment of Emphysema)
- **Hormones**
  - Erythropoietin (Stimulates Production of Red Blood Cells)
  - Insulin (Treatment of Diabetes)
  - Growth Hormone (Treatment of Dwarfism)
- **Other Medically Significant Molecules**
  - Interferon (Treatment of Viral Infections — Some Forms of Cancer)
  - Globulins (Treatment of Wide Range of Diseases ie., Gamma Globulins — Measles)

Cells — Living Organisms

- Beta Cells (May be Cure for Diabetes)
- Lymphocytes (Class) — (Attacks Foreign Cells)

MDAC ELECTROPHORESIS UNIT FOR SPACE PLATFORM





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individual Spacelab experiments in the early 1980s. The subprocesses are, next, expected to be combined into a pilot production plant and tested on vehicles available in the mid-1980s. Finally, it is hoped that actual production plants will fly onboard a space platform in the late 1980s. The involvement of man will be essential for conduct of the early experiments and for tending the pilot plants. The various techniques will not yet be established sufficiently to warrant their automation and man will be needed for adjustments, corrections, sample acquisition, fluid transfers and other operations. When the production plant is established and automated, man will probably be required only for loading and unloading of materials, maintenance and quality testing. Figure 2.7.3.1-1 illustrates, in a matrix form, the role of man in various aspects of orbital biological processing. Figure 2.7.3.1-2 shows the potential mother-ship role of the manned platform for an eventual free-flyer pilot plant.

The pilot plant phase is considered to be still experimental with man intimately involved in most of the included processes. The following two

Figure 2.7.3.1-1

VFP831

ROLE OF MAN IN ORBITAL BIOLOGICAL PROCESSING

	Research Experiments (Early 1980's)	Process Development Testing (Mid-1980's)	Sustained, Quality-Controlled Production (Late 1980's)
Protein Purification	Manned	Semi-Automated (Man-Tended)	Fully Automated (Man-Loading, Unloading and Maintenance)
Cell Purification	Manned	Semi-Automated or Manned	Same as Above
Cell Incubation/ Dissolution and Protein Production	Manned	Manned	Manned

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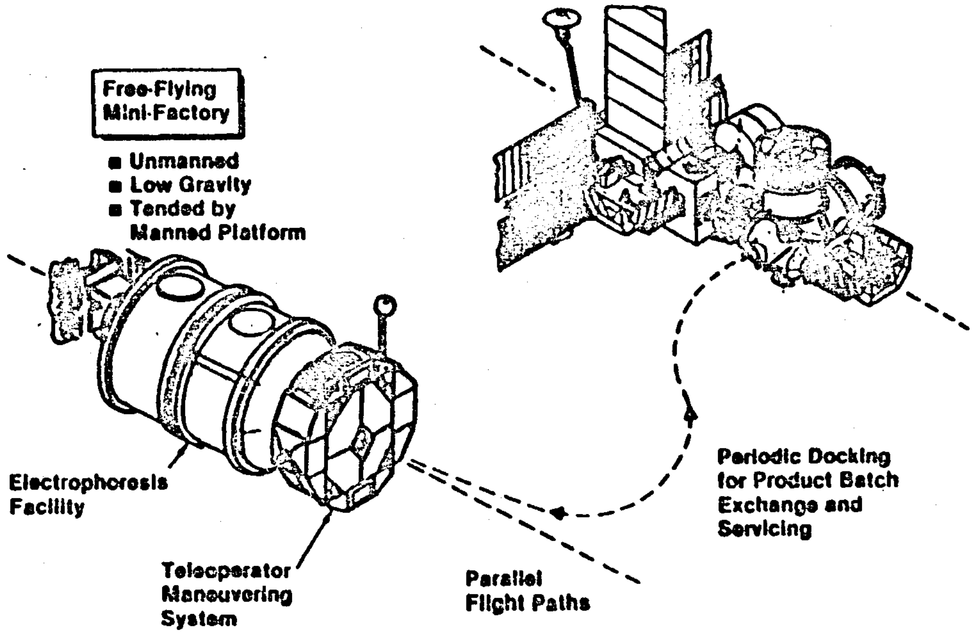
Figure 2.7.3.1-2

PHARMACEUTICAL PRODUCTION



figures, 2.7.3.1-3 and -4, summarize the important steps in biological processing and what man's involvement is in each. The letters A through G on the first chart (2.7.3-1-3) correspond to specific manned activities, identified on the second chart (2.7.3.1-4) and indicate where in the process each will occur. On the second chart an approximately timeline for two production cycles is also shown. Not shown on the charts is the important role that man will play in quality testing of the final product and in pyrolysis testing of the various media during the process to prevent contamination.

2.7.3.2 Continuous Flow Electrophoresis in Space

Electrophoretic separation is not only the most important individual process in the production of biologicals, it is also the process that is expected to most benefit from weightlessness. The McDonnell Douglas Corporation in conjunction with NASA has developed a continuous flow electrophoresis system (CFES) which is scheduled for testing onboard Shuttle/Spacelab. Figure 2.7.3.2-1 illustrates a laboratory model of the system and indicates the advantages expected from the operation of such a system in space. The flight model of the system is expected to be tested initially on early Shuttle flights prior to

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Figure 2.7.3.1-3

TYPICAL SPACE PHARMACEUTICAL PILOT PLANT

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(Manned Involvement: Circled Letters)

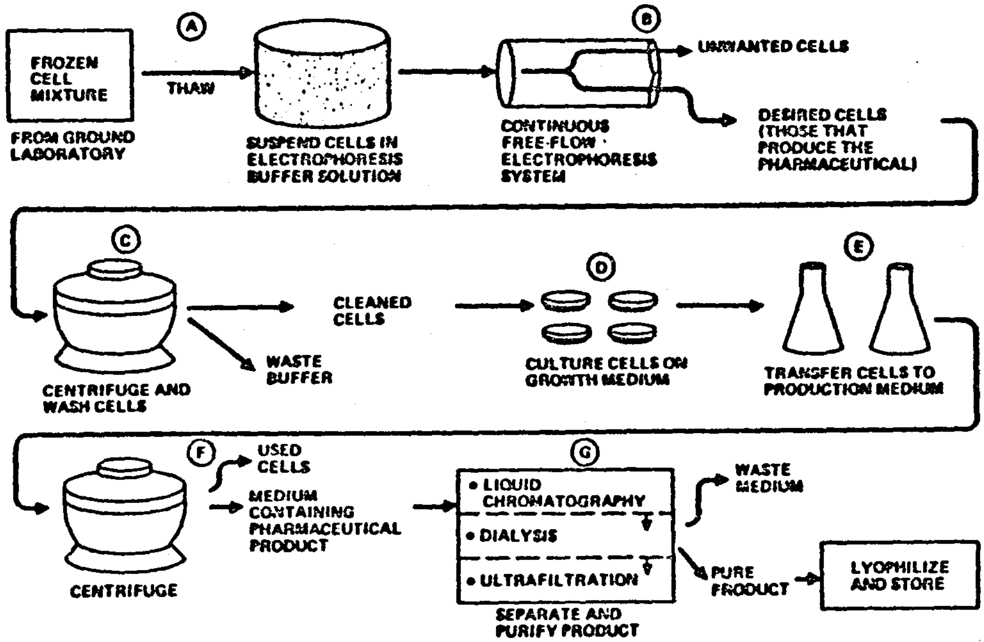
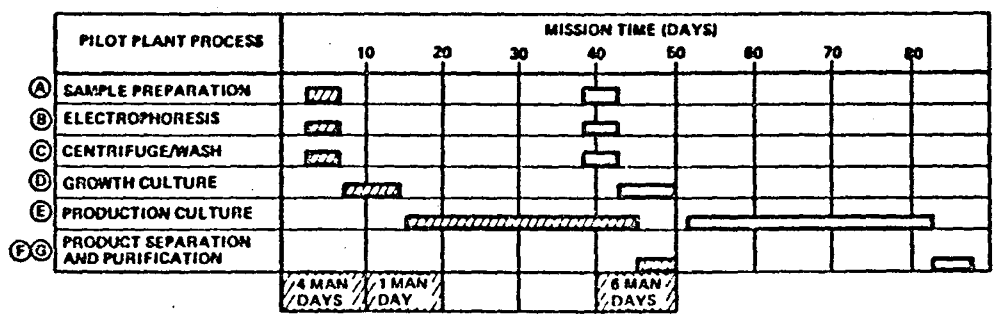


Figure 2.7.3.1-4

TYPICAL TIMELINE PHARMACEUTICAL PILOT PLANT AND CREW OPERATIONS

VFL136N



Ⓐ Thaws Cell Mixture and Suspends in Electrophoresis Buffer Solution

Ⓑ Introduces Cell Suspension Into Electrophoresis Unit and Collects Separated Products

Ⓒ Discards Unwanted Products. Centrifuges Wanted Cells a Number of Times — Resuspending Cells in Fresh Wash Water Between Centrifugations

Ⓓ Prepares Cell Cultures on Growth Medium in Culture Plates

Ⓔ Transfers Cell Colonies to Production Medium and, After Approximately 30 Days, Removes Cells by Centrifugation

Ⓕ Separates Pharmaceutical From Production Medium Via Successive Processes (e.g., Liquid Chromatography, Dialysis, and Ultrafiltration)

Ⓖ Lyophilizes Pure Pharmaceutical and Stores

Figure 2.7.3.2-1

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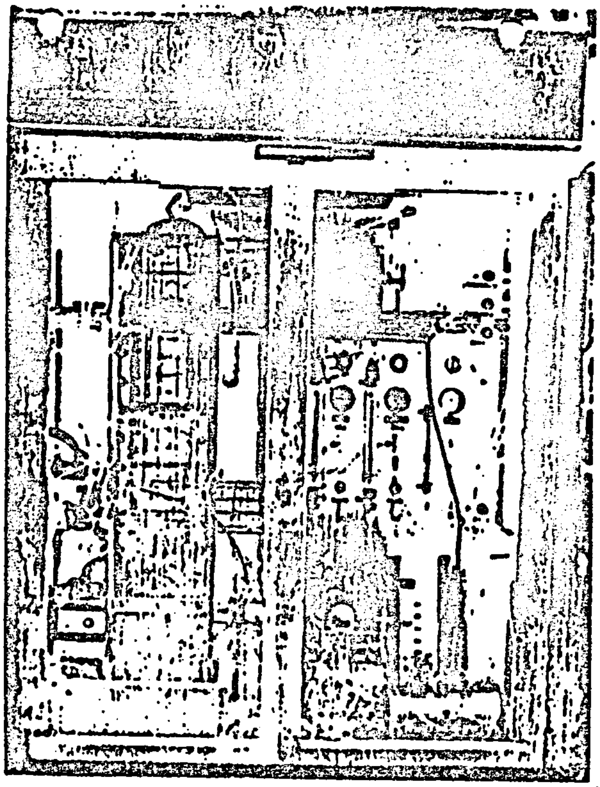

ELECTROPHORESIS OPERATIONS IN SPACE

- AEROSPACE TECHNOLOGY IS OPTIMIZING ELECTROPHORESIS PROCESS
- GROUND OPERATION PROVIDES SEPARATION, BUT NOT THROUGHPUT
- SPACE ELECTROPHORESIS WOULD PROVIDE 100X – 400X THROUGHPUT PLUS GREATER PURITY
- SMALL QUANTITY, HIGH VALUE NATURAL DRUGS NOW COMMERCIALLY FEASIBLE
- JOINT ENDEAVOR AGREEMENT WITH NASA TO DEVELOP SPACE APPLICATION

Spacelab missions. On these early flights the CFES will be installed in the Orbiter middeck in the location which is occupied by the galley on later flights. Figure 2.7.3.2-2 illustrates this installation as well as the location of CFES support equipment.

Following extensive tests of the CFES on the middeck, the system is expected to be expanded and isntalled in three to four racks in the Spacelab module or automated and operated out of the cargo bay. In either case, a sufficient amount of the product is expected to be produced to allow subsequent testing and clinical trials. If the trials are successful, a commercial production unit, consisting of 100 or more chambers, will be developed for use on a manned space platform. Figure 2.7.3.2-3 identifes the steps in the development of a commercial electrophoresis production unit for space. Two potential programs are shown, both commencing with middeck flights and continuing to operations on a manned space platform. A conceptual drawing of an electrophoresis system on a manned space platform is illustrated in Figure 2.7.3.1-4.

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Figure 2.7.3.2-2

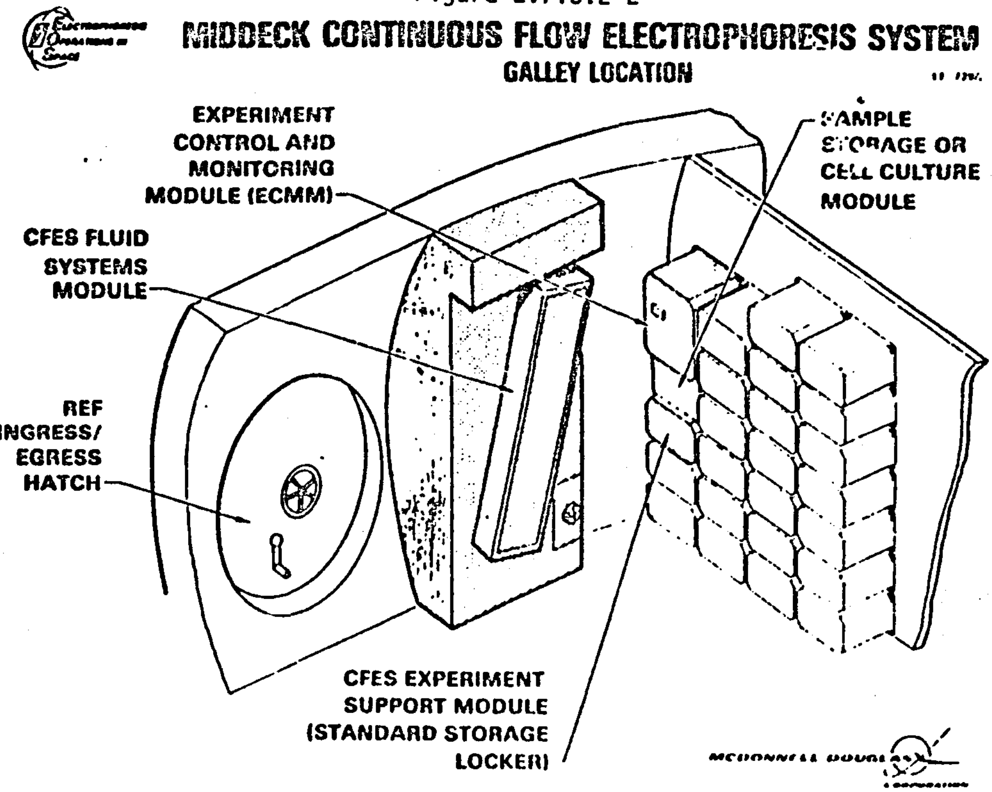

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Figure 2.7.3.2-3

ELECTROPHORESIS FOR HIGH VALUE DRUGS IN SPACE

VFP934

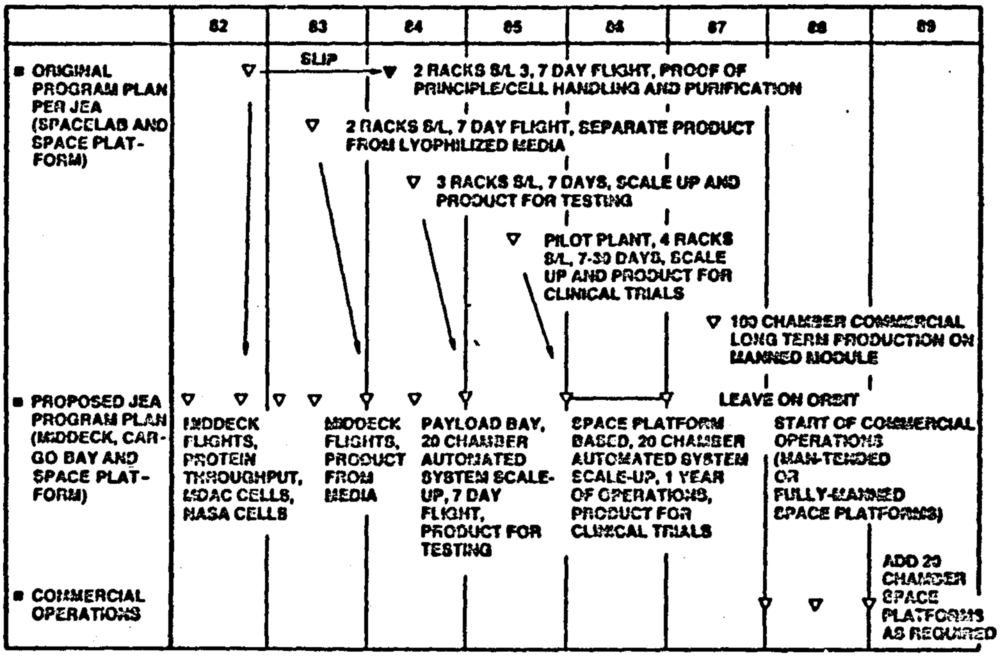
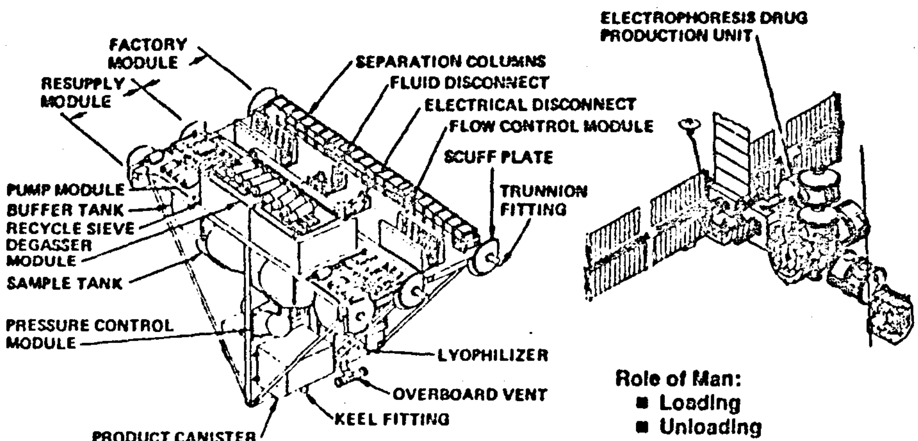


Figure 2.7.3.2-4

ELECTROPHORESIS DRUG PRODUCTION ON MANNED PLATFORM

VFP832



Role of Man:
- Loading
- Unloading
- Quality Control
- Maintenance

("G" Requirement: 3×10^{-3} for 6 Minutes)

2.7.4 Life Sciences Research

Manned missions of the Space Platform are expected to involve crew sojourns of up to 90 days and continuous manning of the platform for indefinitely extended periods. Such missions will be of significant benefit to life sciences research because of (1) the capability to collect medical, physiological and psychological data on the crew for much longer periods than those possible on Spacelab missions and (2) the ability to maintain biological specimens in a weightless environment for one or more life cycles or until the completion of slowly developing phenomena.

Priorities in this science, as defined by MSFC, are as follows: (1) man's problems using man himself where feasible, (2) man's problems using non-human models and (3) basic biological phenomena and principles using a wide range of test species.

2.7.4.1 Biomedical Reserach

This important discipline will, at least during early missions, no doubt involve studies that are associated with physiological changes either observed or investigated onboard Skylab. Skylab research remains, even considering the very long-duration Russian missions, the most extensive and carefully performed studies on man in space, and has bequeathed to us a rich legacy of questions to be resolved and follow-on experiments to be performed. Table 2.7.4.1-1 illustrates the major physiological studies conducted on Skylab crewmen and some of the candidate future studies recommended by Skylab PIs and associated scientists.

Many of these recommended studies involve compensatory changes that occur early in flight or involve test materials that would deteriorate by the mid- to later stages of longer duration missions. Such investigations are most appropriate for conduct on Spacelab missions. Many of these experiments are already designed and scheduled for Spacelab flights. Even after the successful completion, however, of all biomedical research suitable for Spacelab conduct, there will still remain unanswered questions regarding the mechanisms and characteristics of slowly developing adaptations and regarding the complete time-course of potentially debilitating changes. A manned platform will supply the ideal facility for the research needed to answer these questions. Table 2.7.4.1-2

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Table 2.7.4.1-1

PHYSIOLOGICAL CHANGES STUDIES IN SKYLAB CREWMEN

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BODY SYSTEM	OBSERVED CHANGES	CANDIDATE FUTURE STUDIES ON MAN
CARDIOVASCULAR SYSTEM	• LOWER BODY NEGATIVE PRESSURE IMPOSES GREATER STRESS IN WEIGHTLESSNESS THAN IN EARTH'S GRAVITY • POST-FLIGHT ORTHOSTATIC INTOLERANCE • POST-FLIGHT DIMINISHED EXERCISE CAPACITY • RARE INSTANCES OF MILD CARDIA ARRHYTHMIAS • DECREASED CARDIAC OUTPUT POSTFLIGHT– THOUGHT TO BE DUE TO REDUCED VENOUS RETURN	• PERIODIC ELECTRO- AND VECTORCARDIOGRAMS TO RULE OUT MYOCARDIAL DAMAGE • NON-INVASIVE CARDIOVASCULAR DYNAMICS STUDIES (E.G., CARDIAC OUTPUT, ECHOCARDIOGRAPHY, PLETHYSMOGRAPHY, VENOUS COMPLIANCE) AS TECHNIQUES FOR ON BOARD MEASUREMENTS BECOME AVAILABLE • TESTS OF INNOVATIVE EXERCISE PROCEDURES OR OTHER COUNTERMEASURES AS THEY ARE DEVELOPED
MUSCULOSKELETAL SYSTEM	• INCREASE IN URINARY CALCIUM • INCREASE IN URINARY NITROGEN AND PHOSPHORUS • DECREASE IN LEG MUSCLE SIZE AND STRENGTH • MEASUREABLE MINERAL LOSSES FROM THE <u>OS CALCIS</u> (HEEL BONE)	• ONBOARD BONE DENSITOMETRY WHEN TECHNIQUES FOR ONBOARD MEASUREMENTS BECOME AVAILABLE • CORRELATIVE BLOOD AND URINE STUDIES • TESTS OF INNOVATIVE EXERCISE PROCEDURES AS THEY ARE DEVELOPED
FLUID AND ELECTROLYTES, BLOOD, AND THE IMMUNE SYSTEM	• DECREASE IN PLASMA VOLUME • DECREASE IN TOTAL BODY WATER • DECREASE IN RED BLOOD CELL MASS • INCREASE IN EXCRETION OF SODIUM AND POTASSIUM • NET LOSS OF BODY NA^+ (SODIUM) AND K^+ (POTASSIUM) • HEADWARD SHIFT OF BODY FLUIDS • ALTERATIONS IN THE DISTRIBUTION OF RED CELL SHAPES	• DEMONSTRATE PRESENCE/ABSENCE OF GAUER HENRY REFLEX • ISOTOPE STUDIES OF BODY FLUID COMPARTMENTS • INVESTIGATE MECHANISM OF MARROW SUPPRESSION • RENAL FUNCTION STUDIES • HORMONE ASSAY STUDIES • WHOLE BODY ISOTOPE STUDIES FOR ELECTROLYTE CHANGES • RED CELL SHAPE DISTRIBUTION STUDIES
NEUROPHYSIOLOGY, VESTIBULAR SYSTEM	• MOTION SICKNESS • CHANGES IN REFLEX ACTIVITY	• MOTION SICKNESS COUNTERMEASURES • NEUROLOGICAL TESTS AND MEASUREMENTS

Table 2.7.4.1-2

VF0434

RECOMMENDED STUDIES USING MAN ON FUTURE FLIGHTS

STUDIES APPROPRIATE FOR CONDUCT ON SPACELAB FLIGHTS OF SHORTER DURATION (7 – DAYS)	STUDIES MORE APPROPRIATE FOR LONGER DURATION (90 DAYS) FLIGHTS ON A MANNED PLATFORM	TYPICAL MEASUREMENTS AND PROCEDURES ASSOCIATED WITH LONGER DURATION STUDIES
<u>CARDIOVASCULAR STUDIES</u>		
• VECTORCARDIOGRAPHIC MONITORING	• VECTORCARDIOGRAPHIC MONITORING OVER FULL 90 DAYS OF MISSION.	• MEASURE HEART'S ELECTRICAL VECTORS FOR EACH CREWMAN AT WEEKLY INTERVALS
• CARDIOVASCULAR DYNAMIC STUDIES: HEART SIZE AND OUTPUT	• PERFORM CARDIOVASCULAR STUDIES ONLY IF CHANGES HAVE CONTINUED FOR THE ENTIRE DURATION OF SPACELAB MISSION	POSSIBLE MEASUREMENTS OF CARDIAC OUTPUT, ECHOCARDIOGRAPH, VENOUS COMPLIANCE, ETC., ONCE PER WEEK FOR 1ST 30 DAYS, ONCE PER TWO WEEKS FOR REMAINDER OF MISSION – FOR EACH CREWMAN (NOTE – TECHNIQUES NOT CURRENTLY AVAILABLE FOR ONBOARD USE)
• TESTS OF EXERCISE REGIMENS AND OTHER COUNTERMEASURES	• CONTINUED TESTS OF VALUE OF COUNTERMEASURES OVER LONGER DURATION MISSION	• AILY EXERCISE OR USE OF OTHER COUNTERMEASURE;
<u>MUSCULOSKELETAL STUDIES</u>		
• CORRELATIVE BLOOD AND URINE MEASUREMENTS.	• ONBOARD BONE DENSITOMETRY IF TECHNIQUE PERFECTED • CORRELATIVE BLOOD AND URINE STUDIES	• RADIOGRAPHIC SCANNING OR OTHER TECHNIQUE IF DEVELOPED FOR ONBOARD USE AT 14-30 DAY INTERVALS OVER MISSION DURATION
• DEVELOPMENT TESTS OF BONE DENSITOMETRY TECHNIQUES • ISOTOPIC STUDIES OF NITROGEN AND PHOSPHORUS EXCHANGE • INOVATIVE COUNTERMEASURES	• EXERCISE OR OTHER COUNTERMEASURES	• DAILY URINE SAMPLES AND WEEKLY BLOOD SAMPLES PER CREWMAN • EXERCISE/COUNTERMEASURE REGIMEN COMBINED WITH CARDIOVASCULAR PROCEDURES

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Table 2.7.4.1-2 (continued)

RECOMMENDED STUDIES USING MAN ON FUTURE FLIGHTS

VF0433

STUDIES APPROPRIATE FOR CONDUCT ON SPACELAB FLIGHTS OF SHORTER DURATION (7 DAYS)	STUDIES MORE APPROPRIATE FOR LONGER DURATION (90 DAYS) FLIGHTS ON A MANNED PLATFORM	TYPICAL MEASUREMENTS AND PROCEDURES ASSOCIATED WITH LONGER DURATION STUDIES
FLUIDS, ELECTROLYTES, AND BL[illegible] STUDIES		
• DEMONSTRATE GAUER-HENRY REFLEX (MUST BE DONE EARLY IN FLIGHT)	• TOTAL BODY WATER, PLASMA, VOLUME RED BLOOD CELL MASS, NDA EXTRA-CELLULAR FLUID VOLUME	• MEASURED ONCE AT 45-60 DAY OF MISSION IF ISOTOPES WITH SUFFICIENT HALF-LIFE ARE AVAILABLE – MEASUREMENTS CONSIST OF ISOTOPE INJECTION FOLLOWED BY BLOOD AND URINE SAMPLING
• ISOTOPE STUDIES OF BODY FLUID		
• INVESTIGATE MECHANISMS OF MARROW SUPPRESSION	• MARROW SUPPRESSION STUDIES	• BLOOD AND URINE SAMPLING
• RENAL FUNCTION STUDIES	• RENAL FUNCTION STUDIES	• INJECTION OF TEST SUBSTANCES FOLLOWED BY BLOOD AND URINE SAMPLING (AT MISSION DAYS – 30, 60, AND 90, APPROXIMATELY)
• HORMONE ASSAY STUDIES		
• WHOLE BODY ISOTOPE STUDIES FOR ELECTROLYTE CHANGES	• HORMONE ASSAY STUDIES	• BLOOD AND URINE SAMPLING (DAILY URINE, WEEKLY BLOOD)
• PLASMA VOLUME AND RBC MASS	• RBC SHAPE DISTRIBUTION	• BLOOD SAMPLES AT 2 – 3 WEEK INTERVALS
• RED BLOOD CELL SHAPE DISTRIBUTION		
NEUROPHYSIOLOGY, VESTIBULAR SYSTEM STUDIES:		
• ROTATING CHAIR, LINEAR ACCELERATION SLED STUDIES	• MOTION SICKNESS COUNTERMEASURES	• DRUG TESTS AND BIOFEEDBACK STUDIES
• INOVATIVE COUNTERMEASURES TO MOTION SICKNESS	• REFLEX ACTIVITY STUDIES	• REFLEX ACTIVITY MEASURES PART OF GENERAL CLINICAL EVALUATION
• REFLEX ACTIVITY STUDIES		

identifies on which vehicle (Spacelab or Manned Platform) the research recommended in Table 2.7.4.1-1 should best be performed. Table 2.7.4.1-2 also identifies some of the measurements that would be made on the crewmen in conjunction with the biomedical studies on the manned platform.

It may be noted that regular medical measurements onboard the manned platform consisting probably of ECG, blood pressure, body temperature, some pulmonary function measurements and neurological tests will satisfy a number of research requirements. Additional measurement activities consist primarily of the acquisition and preservation of blood and urine samples. Although they are of high priority interest, predictable biomedical procedures are not expected to require a large amount of crew time, allowing, thereby, ample opportunity for other research activities in either the life sciences or other disciplines. Extensive biomedical data will of course be amassed over the many months and years of station life.

2.7.4.2 Research in Space Biology

For the purposes of this report, all life sciences research utilizing sub-human life forms as the experimental subjects is regarded as space biology, regardless of whether the specimen serves a a human model or as the representation of some specific biological characteristic.

2.7.4.3 Long Duration Experiments - Increased Facility Requirements

This section is designed to call attention to the increase in research facilities generally required by long duration experiments. If we wish to derive maximum value from a long duration experiment, it is not sufficient merely to select an experiment designed for a short-duration mission and conduct it over a longer period. Usually, the entire experiment approach as well as the experiment requirements change in order to produce optimal results. To illustrate this thesis, an experiment, typical of those selected and funded for a five-day Spacelab mission, has been chosen as a strawman.

The objective of the strawman experiment, identical for both the short-duration and long-duration approaches, is to determine the effect of weightlessness on rat liver function. Although the objective remains the same, the approach and requirements are significantly different in the two situations. These differences are illustrated in Figure 2.7.4.3-1. The experiment procedures specified on the chart are exemplary only and have not been derived from actual experiment protocols.

On a five-day mission the rats are typically not removed from the holding facility in flight but are all returned intact for post flight studies. No manipulation of the animals by the crew is required; only minimal waste handling and presentation would normally be needed. All inflight measurements such as food and water intake and movement patterns are determined automatically by the holding unit.

If the above procedures were to be extended over a 90-day period, only minimal additional information would probably be gained. If, however, the crew examined and weighed the rats at frequent intervals and if some animals were periodically sacrificed and liver samples obtained and preserved, then a wealth of additional information would be realized. These additional procedures would, however, extensively alter facility requirements and crew time requirements.

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Figure 2.7.4.3-1

SPACELAB 5-DAY MISSION VERSUS MSP 90-DAY MISSION APPROACH AND FACILITY REQUIREMENTS

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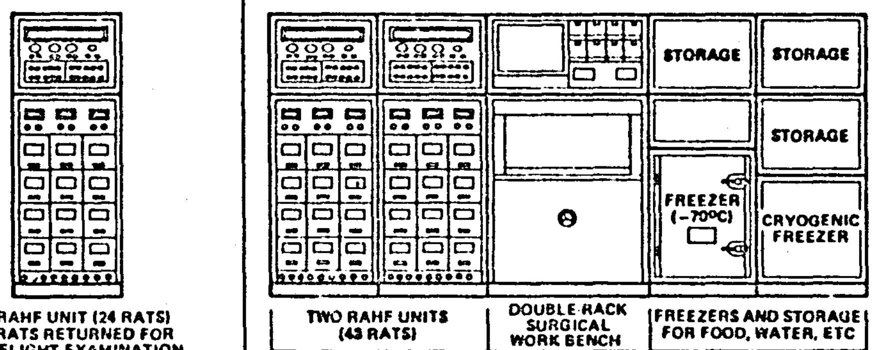
Illustrative Experiment: Effect of Microgravity on Liver Function (Conversion of Carbohydrates to Lipids) in the Rat



SPACELAB 5-DAY MISSION

- ONE RAHF UNIT (24 RATS)
- ALL RATS RETURNED FOR POSTFLIGHT EXAMINATION
- NO INFLIGHT RAT MANIPULATION
- SINGLE DIET FOR ALL RATS
- FOOD AND WATER INTAKE MONITORED
- RAHF ESSENTIALLY SELF-CONTAINED – VERY LITTLE ADDITIONAL STORAGE NEEDED

MSP 90-DAY MISSION

- RATS EXAMINED AND WEIGHED DURING FLIGHT
- RATS PERIODICALLY SACRIFICED AND LIVER SAMPLES REMOVED
- CRYOGENIC FREEZER USED FOR QUICK-FREEZE OF LIVER SAMPLES
- FREEZER (-70°C) USED TO STORE SAMPLES AND RAT CARCASSES
- 12 RATS RETURNED FOR POSTFLIGHT EXAMINATION
- SEVERAL EXPERIMENTAL DIETS INVOLVED

The periodic sacrifice of rats would, consequently, increase the number of experiment specimens used and require a second RAHF unit. Rat examination, weighing, sacrificing and tissue sampling would all be performed on a surgical facility such as a general purpose workbench furnished with pertinent instrumentation and supplies. The preservation of liver samples would require both a cryogenic freezer for the tapid preparation of frozen samples and a -70°C freezer for their long-term storage as well as for the storage of rat carcasses. Increased requirements are expected to be typical for almost all space biology experiments converted from short-duration to long-duration missions. This condition is summarized in Figure 2.7.4.3-2.

Not only will facility requirements, in this case, be increased by a factor of six but the demands on crew time per week will almost double. Figure 2.7.4.3-3 illustrates that the specimen monitoring and support activities performed by the crew on a short-duration mission will require only a little over six hours for the total mission, whereas, the activities required for the 90-day

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Figure 2.7.4.3-2

CONVERSION OF LIFE SCIENCE PAYLOADS FROM 7- TO 120-DAY DURATION

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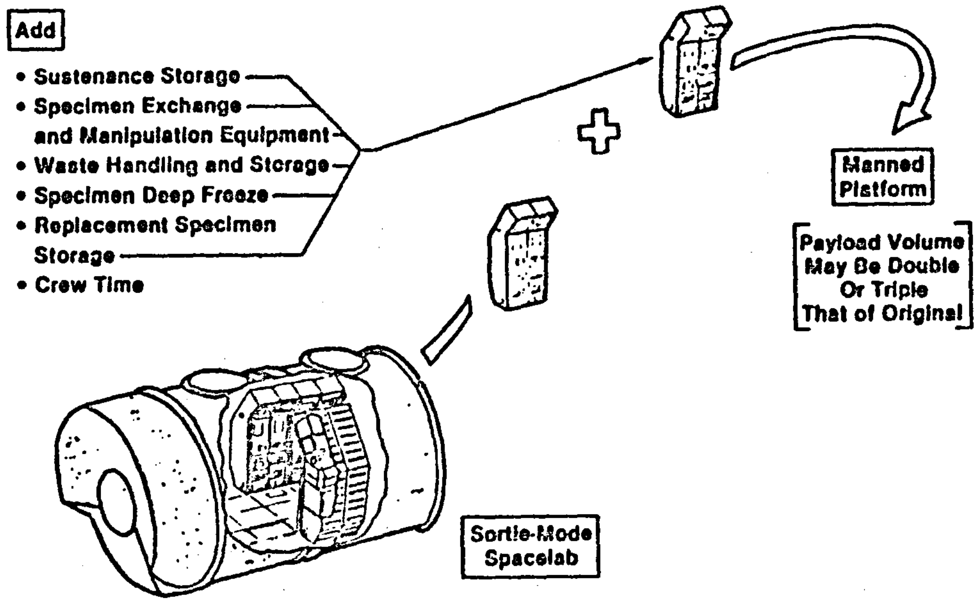

Figure 2.7.4.3-3

SPACELAB 5-DAY MISSION VERSUS MSP 90-DAY MISSION CREW TASK TIMES

VFK722N

Illustrative Experiment: Effect of Microgravity on Liver Function in the Rat

CREW TASKS	TASK TIMES (IN MINUTES)																		
	WEEK 1												WEEK 2	WEEKS 3&4	WEEKS 5&6	WEEKS 7&8	WEEKS 9&10	WEEKS 11&12	WEEK 13
	DAY 1		DAY 2		DAY 3		DAY 4		DAY 5		DAY 6	DAY 7							
	5	90	5	90	5	90	5	90	5	90									
1. MONITOR RAHF EC&LS AND SPECIMEN WELL BEING	15	30	15	30	15	30	15	30	5	30	30	30	60	180	180	180	180	180	60
2. MONITOR SPECIMEN FOOD AND WATER INTAKE	10	20	10	20	10	20	10	20	5	20	20	20	40	80	80	80	80	80	40
3. REPLENISH FOOD AND WATER					25	60					60		120	240	240	240	240	240	60
4. PERFORM WASTE MANAGEMENT TASKS					60	120					120		300	600	600	600	600	600	180
5. PERFORM SPECIMEN EXAMINATION WEIGHING, PHOTOGRAPHY								140		140	140	30	840	720	500	400	300	240	60
6. CONDUCT SPECIMEN DISSECTION AND SAMPLE ACQUISITION AND PROCESSING												90	90	90	90	80	90	90	0
7. PREPARE AND CLEAN UP WORK-BENCH AREA								15		15	15	30	60	60	60	60	60	60	15
8. PREPARE FOR SPECIMEN AND SAMPLE RETURN									180										300
FIVE DAY MISSION TOTALS	25		25		115		25		190		= 390 MINUTES = 6-1/2 HR								
90 DAY MISSION TOTALS	50		50		230		205		205		385	200	1510	1890	1750	1640	1520	1490	715
	TOTAL = 11,815 MIN = 196.9 HR = 14.9 HR PER WEEK																		

experiment would require almost 11 hours for a comparable period or about 194 hours for the total mission. Examples of crew time requirements for other typical life sciences experiments are shown in Figure 2.7.4.3-4.

2.7.4.4 Life Sciences Research on Early Manned Platform Missions

The preceding section discussed the increased requirements that are typical of converting from short- to long-duration missions. Early manned platform missions are not expected, however, to be able to afford the luxury of large enclosed volumes and extensive crew time devoted solely to experiments, life sciences or otherwise. The initial manned platform is expected to incorporate only a short module dedicated to crew habitation which may include, at most, two double racks for experiment equipment. For such configurations, experiments will have to be carefully selected to prevent their overburdening available space and crew time and yet be appropriate for long-duration missions and be able to yield information of value over the full 90, or more, days of the mission.

Figure 2.7.4.3-4

ESTIMATED CREW TIMES FOR TYPICAL EXTENDED-DURATION LIFE SCIENCES EXPERIMENTS

VFK723N

EXPERIMENT TITLE	DURATION (WK)	NUMBER OF CREWMEN	AVERAGE CREW TIME (MIN PER DAY)
HUMAN VESTIBULAR FUNCTION	6	2 OR MORE	15 PER CREWMAN
CHANGES IN HUMAN BLOOD VOLUME	6	2 OR MORE	10 PER CREWMAN
CHANGES IN HUMAN CIRCULATORY DYNAMICS	6	2 OR MORE	2 PER CREWMAN
HUMAN LUNG COMPLIANCE AND PULMONARY RESISTANCE	8	2 OR MORE	7 PER CREWMAN
LUNG CLEANSING AND TRAUMATIC INJURIES IN RATS	6	1	75
RADIATION TOLERANCE IN ANIMALS	7	1	165
DROSOPHILA BEHAVIOR AND LIFE-CYCLE PHENOMENA	13	1	130
BEETLE DEVELOPMENT IN WEIGHTLESSNESS	13	1	17
PLANT GROWTH AND DEVELOPMENT	12	1	13
DEVELOPMENT OF CHEMICAL ABNORMALITIES IN PLANTS	8	1	143

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Figure 2.7.4.4-1 presents three space biology experiments that exemplify the characteristics discussed above. The experiments are maintained in three relatively self-contained modules; they require only a minimum of support equipment and supplies, all of which share the double rack with the experiment modules. Any required specimen manipulation and examination can be conducted on the surface of the General Purpose Workbench which is part of the habitability module equipment and will require a maximum of eight manhours per day. Figure 2.7.4.4-2 identifies the major activities typical of the three experiments and group them into experiment periods included in a 24-hour crew timeline.

Figure 2.7.4.4-3 depicts the timelines for three manned platform crewmen for a typical day of an early mission. The daily timelines allocate eight hours for sleep, eight hours for experiment activities, one hour for station-keeping, three hours for meals, two hours and 30 minutes for leisure time and 30 minutes each for medical measurements (sustained for months, maybe years), pre-sleep activities and post sleep activities. The activities identified on

Figure 2.7.4.4-1

LIFE SCIENCES
MANNED PLATFORM PROGRAM
(EXAMPLE 90-DAY ACTIVITY)

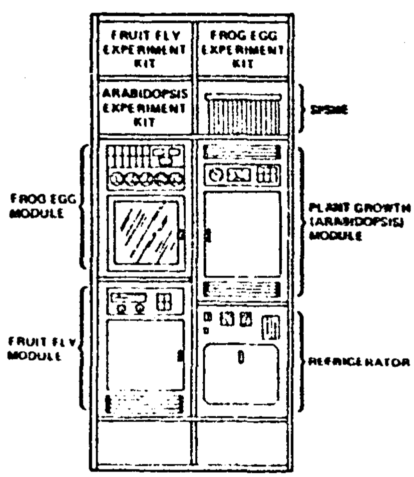
VF0676

SPACE BIOLOGY EXPERIMENTS

- EFFECTS OF WEIGHTLESSNESS ON FROG EGG FERTILIZATION AND LARVAL MORPHOGENESIS (90-DAY CYCLE)
- ARABIDOPSIS PLANT GROWTH, DEVELOPMENT, AND HEREDITY IN ZERO G (21-DAY CYCLE)
- DROSOPHILA (FRUIT FLY) BEHAVIOR AND LIFE CYCLE PHENOMENA IN ZERO G (15-DAY CYCLE)

SELECTION CRITERIA

- HABITAT-COMPATIBLE
- TWO-RACK ALLOCATION
- EXTENSIVE CREW INVOLVEMENT
- MODERATE INVESTMENT



CREW ACTIVITIES

- INDUCE OVULATION
- HARVEST FROG EGGS AND SPERM
- MIX EGGS AND SPERM IN MODULE CONTAINERS
- ENSURE PHOTOGRAPHY AND SPECIMEN FIXING AT PRESCRIBED INTERVALS
- HARVEST ARABIDOPSIS SEEDS AND PLANT IN AGAR MEDIA
- PRESERVE MATURE PLANT PARTS AS PRESCRIBED
- ENSURE PLANT MODULE OPERATION AND ENVIRONMENT CONTROL
- MAINTAIN DROSOPHILA COLONY
- SEPARATE MALE/FEMALE FLIES
- OBSERVE FOR MUTATIONS
- MONITOR DROSOPHILA BEHAVIOR
- COUNT EGG BATCHES
- MAINTAIN MORTALITY RECORDS
- ENSURE OPERATION OF DROSOPHILA MODULE

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Figure 2.7.4.4-2

TYPICAL EXPERIMENT ACTIVITY TIMELINES

VFO782

LIFE SCIENCES EXPERIMENTS

1 Hr

Period F, Earth Equivalent Time 8:00 am to 9:00 am

Frog Egg Experiment Data Collection (AFTER OVULATION)

- Check Experiment Module Temperature, O_2 and CO_2 Levels
- Check Adherence to Fixative Injection Schedule
- Check No. of Exposed Frames in Time-Lapse Photography — Compare With Schedule
- Remove Container Holding Most Recently Fixed Specimen — Examine Progress and Development With Hand Lens
- Record Data

2 Hrs

Period G, Earth Equivalent Time — 10:00 am to 12:00 Noon

Drosophila Colony Maintenance

- Check Displays For Automatically Controlled Temperature and Humidity
- Check Each Drosophila — Containing Capsule in Module
  - — Examine For Amount of Yeast Growth — Reinnoculate As Necessary
  - — Note Newly Deposited Egg Batches and Record Capsule Number
  - — Note Occurence of Dead Flies — Record No. and Capsule
- Record Data

2 Hr

Period H, Earth Equivalent Time — 1:00 pm to 3:00 pm

Arabidopsis Seed Harvesting and Replanting

- Remove Arabidopsis Experiment Kit From Storage and Setup on Workbench
- Remove Arabidopsis Growth Tubes From Refrigerator and Allow to Warm
- Remove, Separately, Arabidopsis Plants From Experiment Module
- Harvest Seeds, Replant Some in New Tubes, and Package Remainder For Return
- Label Seed-Containing Tubes and Return to Experiment Module
- Examine Mature Plants For Abnormalities — Record Observations
- Remove Specified Plant Parts, Preserve, and Prepare For Return. Dispose of Rest of Plant
- Return Kit to Storage and Dispose of Used Tubes

3 Hr

Period I, Earth Equivalent Time, 4:00 pm — 7:00 pm

Drosophila Experiment Activities

- Remove Drosophila Experiment Kit From Storage and Setup on Workbench
- Remove Drosophila Container From Experiment Module Previously Noted to Contain Egg Batches
- Anesthetize and Remove Flies
- Using Hand Lens, Separate Males From Females
- Obtain New Containers From Refrigerator
- Place Some Males in One, Females in Another
- Package Remaining Flies For Return
- Using Hand Lens, Count No. of Eggs in Each Egg Batch
- Record Data and Return Containers to Experiment Module

- Remove Containers With Newly Hatched Flies
- Anesthetize Flies, Separate Males From Females, and Examine For Abnormalities
- Place Some Males in One New Container, Females in Another
- Package Remainder For Return

- Remove Containers With Male Flies and Female Flies Which Have Just Reached Maturity
- Anesthetize Flies and Place Some Males and Some Females in New Container
- Allow to Recover and Observe Mating Behavior
- Return Containers to Experiment Module
- Record Observations and Data

- Remove Containers Previously Noted to Contain Dead Flies
- Anesthetize Flies and Remove Dead Specimens
- Package Dead Flies For Return
- Record Longevity Data

- Repack Kit and Return to Storage
- Dispose of All Used Containers and Supplies

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Figure 2.7.4.4-3

CREW TIMELINE — 3 CREWMEN
TYPICAL MISSION DAY

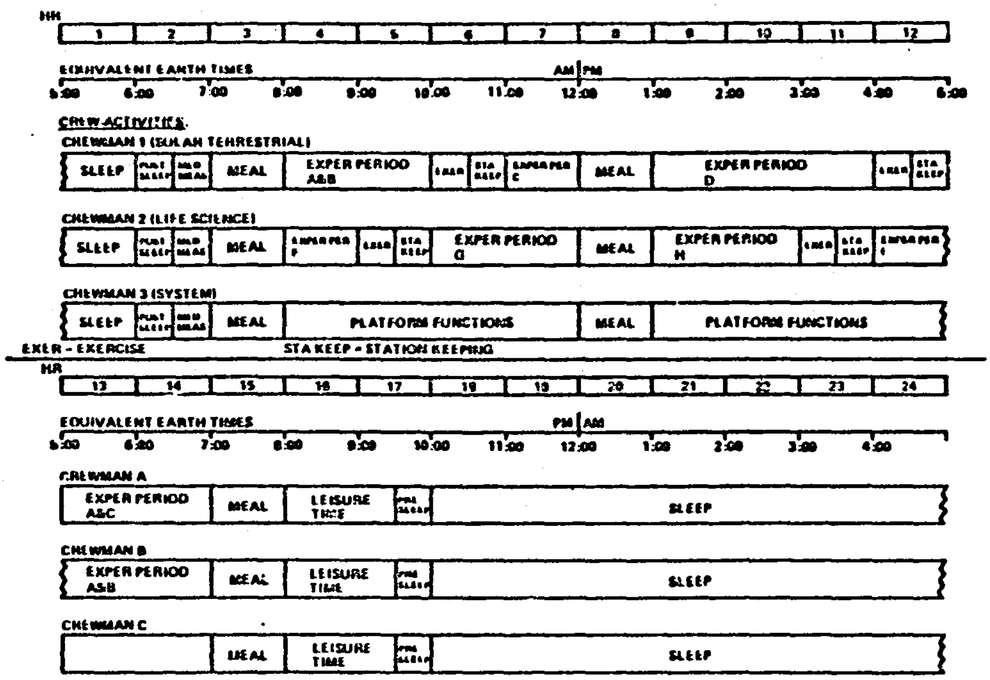

Figure 2.7.4.4-2 for the three life sciences experiments are shown as experiment periods on Figure 2.7.4.4-3 as part of the timeline for Crewman No. 2.

Detailed definition of the character or accommodation of individual payloads was not called for in the Statement of Work or possible in this size study. Therefore, any follow-on efforts on the space station should begin with the following:

- A list of medical research hardware needed.
- An accommodation analysis showing where equipment should be located on a priority basis.
- A timeline analysis of crew time requirements to do the research.
- A confirmation of the residual accommodations available for space biology research equipment.
- A discussion of options and advantages of locating medical and/or space biology research equipment in various modules of the station.

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Such an activity should of course be coordinated with the ongoing MSFC/Ames/JSC planning for Life Science flight experimentation for the 1990s.

2.7.5 Rendezvous Sensor and Control Testing

Future operations in low earth orbit will involve a considerable amount of remotely-controlled vehicle operations including the following:

- Excursions of Teleoperator Maneuvering System (TMS) for modular assembly ahd replacement, sensor target deployment and retrieval and remote environment measurement.
- Unmanned logistics vehicle rendezvous (and relaunching of reentrable).
- Orbital Transfer Vehicle (OTV) dispatching to remote location before engine firing.
- Unmanned spacecraft acquisition for servicing.
- Subsatellite payload vehicle redocking for servicing or materials processing product removal for return to ground.

Although the U.S. has had considerable experience in the rendezvous and docking of manned vehicles, considerable development and test activities are in prospect to acquire a routine unmanned rendezvous capability.

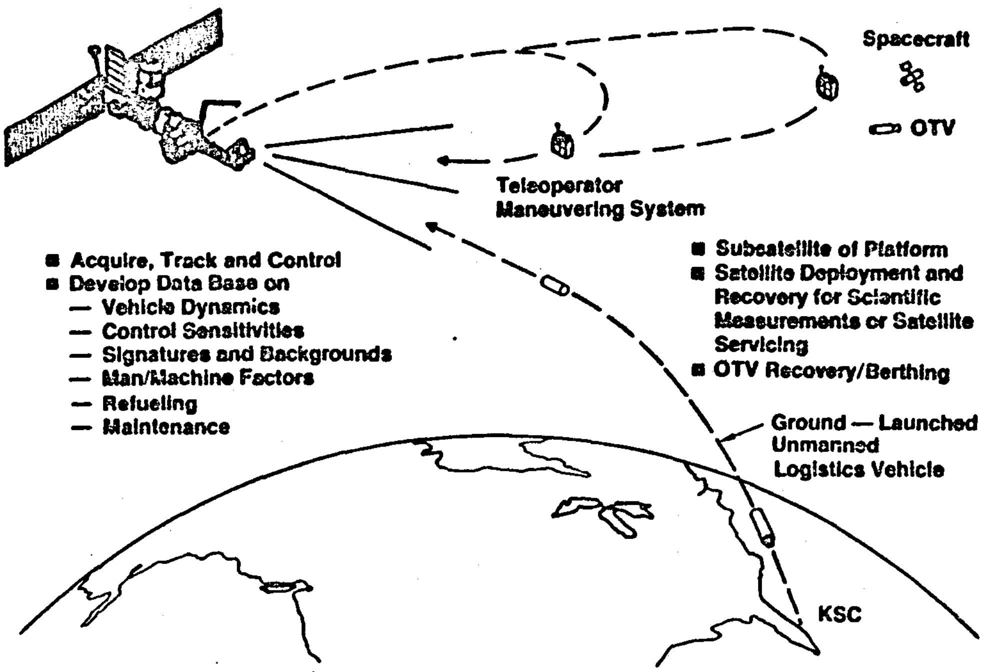
For several years now, the U.S.S.R. has been using unmanned Progress spacecraft as well as Soyuz manned spacecraft which have been converted for logistics to support the Salyut 6 space station. International news media reports indicated troubles in early flights of the Progress which can be an indication of the challenge of development involved.

In any event, as shown in Figure 2.7.5-1, the manned space platform can serve as a flight test base for the development of rendezvous sensors, controls, techniques and prototype spacecraft.

Figure 2.7.5-1

RENDEZVOUS, RECOVERY AND CONTROL TESTING

VFP028



The development/prototype testing to be performed on the manned space platform would progress from early tests on subsystems and sensors to eventual vehicles for the determination of performance envelopes, interface constraints and safety precautions.

The on-orbit test activity requires an exterior berth for equipment, special control console and data acquisition system (including telemetry antenna and perhaps a TV antenna for closed-loop visual-based control) and viewing ports and documentary TV and camera coverage much like a test facility on earth.

The role of man in such testing is as significant as that in dynamic flight simulations on earth and would include such functions as those defined in Figure 2.7.5-2.

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Figure 2.7.5-2

VFP930

ROLE OF MAN IN RENDEZVOUS TESTING

FOR APPROACHING IN-FLIGHT TARGETS (GROUND OR ORBITAL LAUNCHED)

- Activate Sensor (Radar or IR) and Initiate Autotrack Mode; Initiate Control of Approaching Spacecraft
- Observe Sensor Output on Display Screen (Sensor in Autoscan Mode Based on Tracking Data Input); Monitor Spacecraft Status
- Differentiate Target from Clutter
- Adjust for Any Sensor or Environment Problems
- Documentary Photograph Incoming Spacecraft
- Coordinate Operations with Auxiliary Tracking
- Modify Measurement and Control Approach as Required by Anomalies or Experimental Objectives; Repeat Tests as Required

FUNCTIONS FOR ORBITAL DEPLOYMENT AND/OR RETRIEVAL OF SATELLITES

- Manipulate Subsatellite From Stowage Position to Docked Teleoperator Maneuvering System (TMS)
- Checkout and Deploy Subsatellite/TMS to Set Distance From Manned Platform, Orient as Required
- Activate Radar or IR Sensor, Tracking Support System, and TMS/Payload Control System and Control Flight
- Activate Payload and Perform Operation

  [Retrieve Satellites with TMS if Conducting Servicing]
- Monitor Status of TMS/Satellite for Control and Safety
- Return TMS/Satellites to Manned Platform for Berthing

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2.7.6 Environmental Control and Life Support (ECLS) Technology

Although the initial configuration of the manned space platform (MSP) is conceived to have an elemental ECLS subsystem capability, later growth configurations will have increasingly more efficient but more complex equipment.

It is further conceived that much of each subsystem in the manned space platform will be highly modularized not only for on-orbit servicing and/or replacement in the event of failure, but also to permit modular upgrading of capabilities when needed for growth without returning the vehicle to earth.

Part of the activity on the manned space platform will be dedicated to development testing of advanced subsystem modules, such as ECLS, putting them temporarily on-line in the system to test performance and sensitivities in zero-g plus other real environments and loads, before commitment to final design.

Figure 2.7.6-1 illustrates one candidate approach to progressive, modular development of an advanced ECLS capability. Figure 2.7.6-2 presents an

Figure 2.7.6-1

LIFE SUPPORT SYSTEMS TEST PROGRAM FOR MSP

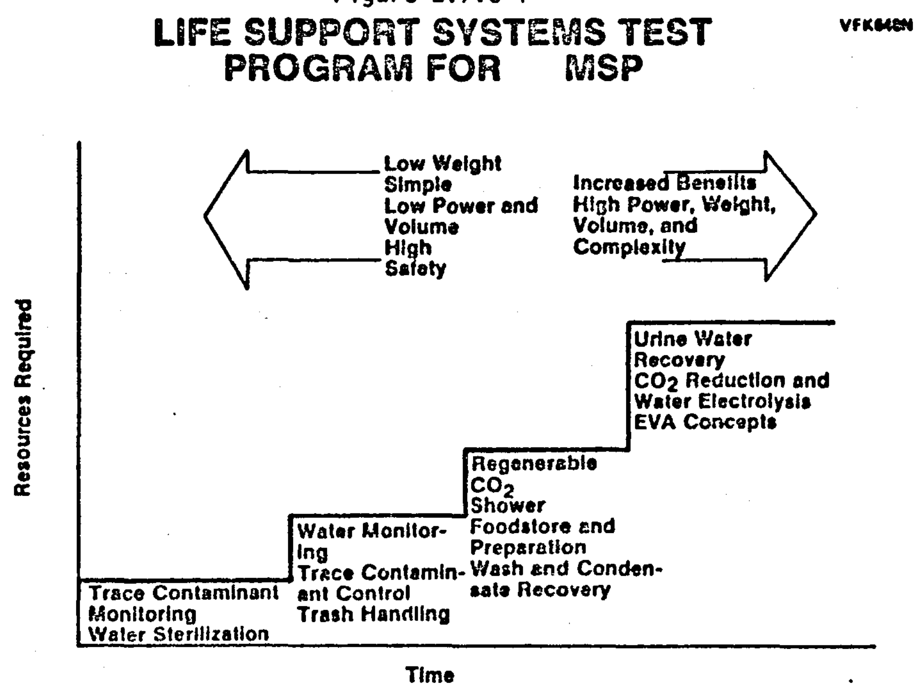

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Figure 2.7.6-2

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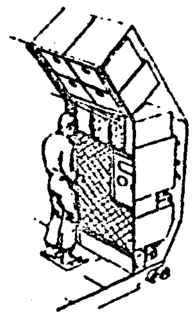
VAPOR COMPRESSION URINE WATER RECOVERY

OVERALL OBJECTIVE: SIGNIFICANTLY REDUCE EXPENDABLE RESUPPLY

MISSION PURPOSE: VERIFY DESIGN CONCEPT IN ZERO g

PLATFORM REQUIREMENTS:



- **DOUBLE RACK MOUNTED**
- **WEIGHT 302 LB**
- **POWER 70W AVG, 211W PEAK**
- **COOLING 297 BTY/HR AVIONICS 491 BTU/HR CABIN AIR**
- **PROCESSING 20.5 LB/DAY**

overview of one possible technology development payload, namely, vapor compression urine water recovery. The objective for eventual incorporation of such a capability into the manned space platform is to reduce the storage and logistics involved in handling of many pounts of waste water produced each day.

As part of their subcontract, Hamilton Standard also provided material on subsystem flight technology verification for ECLS as presented below.

2.7.6.1 ECLS Subsystem Demonstration (Hamilton Standard Input)

The evolutionary growth concept of the Manned Sapce Platform offers the unique capability to perform verification and demonstration testing of growth ECLS concepts on Shuttle and early MSP missions. It is anticipated that subsystems would first be demonstrated on Spacelab or Orbiter and followed by life verification on early MSP. In this manner, zero-gravity compatibility is demonstrated on a short-duration mission where modification and retest on subsequent launches is possible. The use of early MSP for life verification, rather than just demonstration, will save extensive and redundant ground

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testing as well as provide an early improvement in crew amenities. The demonstration subsystems do not provide primary functions during the early missions. They are intended to establish certification and confidence for later missions. As such, these units may be scaled or modularized to provide only a portion of their ultimate performance.

The following discussion is divided into three sections. The first presents the candidate vehicles and their advantages and limitations for demonstration-type hardware testing. The second section presents ECLS functional groups and preliminary rationale for an in-orbit demonstration program. The third section describes how the demonstration and evolutionary subsystem can be physically implemented into the MSP vehicle.

2.7.6.1.1 Vehicle Considerations - Shuttle Orbiter: The Shuttle Orbiter represents the most advantageous vehicle to perform certain subsystem and zero-gravity demonstrations because of numerous flights and availability of critical resources such as food preparation, hygiene, commodes and greater water storage capability.

The Orbiter would be the primary vehicle to demonstrate hygiene subsystems such as a shower and clothes washer. The wash water produced in those units could either be stored or used to demonstrate wash water processing equipment such as TIMES or VCD. Urine is also available for processing in the Orbiter.

The MSP CO_2 removal subsystem (SAWD) is competitive with the Orbiter CO_2 removal subsystem (LiOH) in weight and voluem for baseline Shuttle missions. As such, use of SAWD as the primary CO_2 system on Orbiter could accumulate sufficient hours on the many Shuttle missions anticipated prior to MSP to provide the life verification needed for the initial platform For this reason, Orbiter is recommended as the primary vehicle for SAWD.

Spacelab: The Spacelab is designed for experiments and experiment packages. Experiments, in general, must be self-contained. Convenient interfaces are mounting support structure, power, air-cooling and data acquisition.

The Spacelab missions of up to seven days limits its use to zero-gravity demonstration only. Life certification for MSP requires much longer missions than Spacelab will provide.

Spacelab is ideal to evaluate condensate processing and water quality monitoring because of the availability of condensate water. Air systems such as SAWD and catalytic oxidation could use Spacelab as a demonstration vehicle. Maintenance demonstrations on components and component subassemblies would also be conducted in Spacelab.

Early MSP: As previously discussed, the early MSP missions are ideal to provide life verification of subsystem needed for the growth platform. Demonstration tests are not recommended for the MSP because unacceptable performance would result in the having to carry the subsystem as dead storage for 90 days or until the next resupply period.

Incorporation of Shuttle demonstrated hygiene subsystems such as a shower and clothes washer on the early platform together with wash water processing will have direct crew benefits even if these subsystems are only available on a limited basis.

Subsystems, such as Solid Polymer water electrolysis and Sabatier CO_2 reduction, which are not required until the final MSP growth step, can be used for life verification on the early platform without prior demonstration on Shuttle or Spacelab.

2.7.6.1.2 Subsystem Considerations - A preliminary scenario for in-flight verification of each ECLS subsystem is presented in the following tables. The subsystems are divided into four major functional groups: Atmosphere, Water Processing, Hygiene and Maintenance Demonstration. Integration between water processing and hygiene is required, as discu-sed in the tables to balance the inlet/outlet flows of both subsystems. The other major integrated test occurs during the intermediate MSP configuration where the demonstration electrolysis and CO_2 reduction subsystems will be integrated with the baseline CO_2 removal subsystem to perform closed loop atmospheric testing.

2.7.6.1.3 Implementation Considerations - Two major options are being considered to physically install the demonstration hardware and final growth hardware into the MSP. The first option requires designing the initial platform with adequate provisions (mounting, plumbing interfaces, power and control interfaces) to install the growth hardware during the evolutionary phasing and demonstration test missions. This option, recognizes that considerable consumables are launched with the initial platform since no logistics module is planned until the first resupply period. For example, the consumable tanks might be located where the growth ECLS subsystems could eventually be installed. All packages and tanks must then be designed for transfer and easy installation. As demonstration and growth hardware packages are launched, they will be installed in their predesigned locations. The empty tanks will be transferred to the logistics module for return to earth.

The second option uses special ECLS modules to package the demonstration and growth hardware. A module can be tailored for each mission phase. The module would attach to the Airlock Adapter and be replaced as mission needs and ECLS configurations change. The ECLS module option becomes attractive if a Logistics Module is used on the initial platform and equipment volume is not available for evolutionary equipment growth within habitable modules.

Sketches of the two options are shown in Figures 2.7.6.1.3-1 and -2. The first option uses the space allocated in the Airlock Adapter to package the ECLS equipment. The main complexity of this approach lies in the requirement to front load significant engineering effort associated with the design and installation of growth systems during the preliminary design phases of the MSP program. The major drawback of the second option is the requirement for a new module. However, one-segment modules are planned for many platform experiments and its use for ECLS subsystem could represent a minimum development cost. Initially, the ECLS module would attach to a port on the Airlock Adapter. In its final configuration, when reliance on closed loop ECLS has been certified, the logistics requirements are reduced to a single segment module size and both modules are installed in tandem. The Logistics Module is replaced at its normal schedule period. Replacement of the ECLS module is easily achieved at the same time if a major overhaul or significant hardware improvement is scheduled. Otherwise, single subsystem replacements would be accomplished in orbit.

Figure 2.7.6.1.3-1

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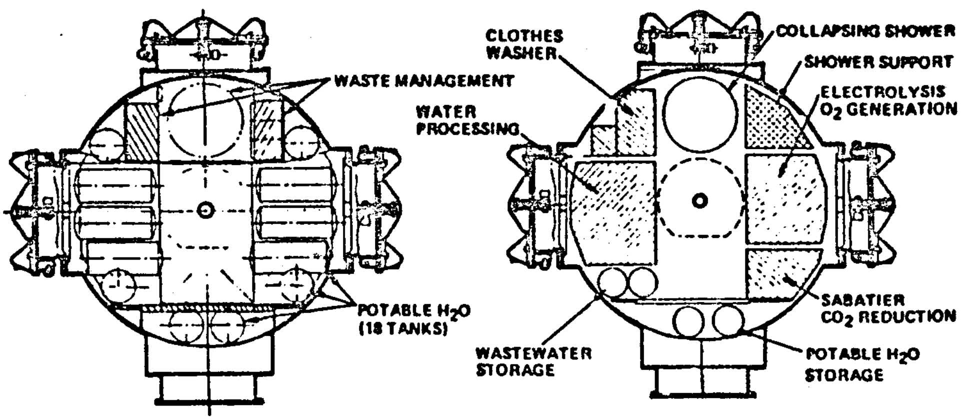
AIRLOCK ADAPTER WITH GROWTH ECLS SUBSYSTEMS INSTALLED



Airlock Adapter Showing Equipment Rq'd for 1st 90 Days Only

Airlock Adapter With Growth ECLS Subsystems Installed

Figure 2.7.6.1.3-2

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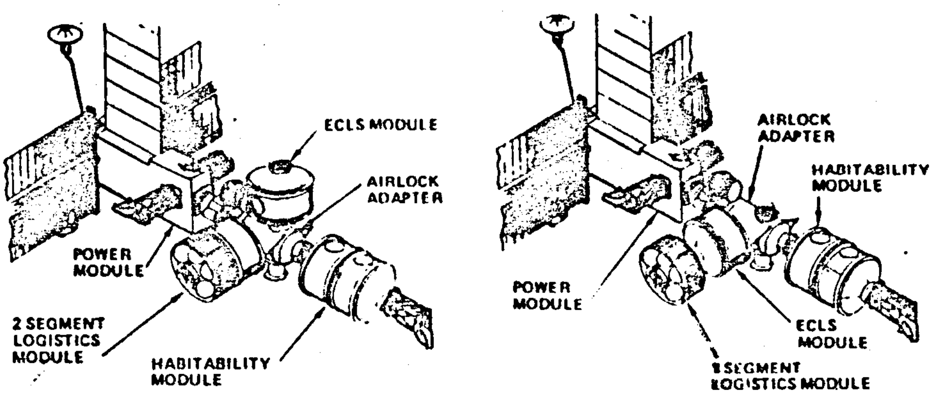
ECLS MODULE CONCEPT

Initial Configuration With ECLS Module

Growth Configuration



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2.7.6.1.4 Technology Verification Logic - The following charts (Table 2.7.6.1.4-1) describe the MSP requirements and technology verification logic for each functional group of ECLSS hardware.

2.7.7 Deployable Structure Technology

The growing size of space vehicle sizes create a continuing need for various approaches to compacting structures into the Shuttle cargo bay for delivery to orbit.

Although many innovative mechanism approaches to compaction have been ventured, the integrated performance in the orbit environment, for deployment, rigidization and sustenance of design rigidity, is difficult to model analytically and most assuredly require in situ testing.

In Figure 2.7.7-1 a representative deployable structure is shown along with all of the attendant test functions and sources of problems defined in a recent in-house MDAC study. In addition, an approach is shown for measuring deformation of such a beam with a dual-laser instrumentation setup.

This particular type of deployable structure was designed for use in compact delivery of sections of a very large, (Advanced) Science and Applications Space Platform which were studied for NASA/Langley through MSFC (MDAC report G8533, July 1980) to accommodate those extremely large payloads identified by the science community for the mid to late 1990s. The concept is illustrated in Figure 2.7.7-2 and features individual structural arms of 60 meters and an overall span of 125 meters. The design of an individual section is shown in Figure 2.7.7-3. The performance accuracy budget elements for such a structure are as follows:

- Materials
  - Short-term E, variations
  - Long-term E, variations (radiation)
  - Creep
- Structures
  - Thermal distortion
  - Stiffness
  - Dynamic response
  - Damping

Table 2.7.6.1.4-1

MSP/ECLSS REQUIREMENTS AND VERIFICATION LOGIC

FUNCTIONAL GROUP	MSP REQUIREMENTS			VERIFICATION LOGIC		
SUBSYSTEM	INITIAL	INTERMEDIATE	GROWTH	GROUND	SHUTTLE/SPACELAB	MSP
ATMOSPHERE						
Atmosphere Monitor	X	X	X	Complete Mapping Of Performance For Anticipated Atmosphere Constituents	Use Spacelab GAMS Unit On MSP	Certification Needed Prior To MSP
CO_2 Removal (SAWD)	X	X	X	Life Test	Zero-Gravity Demonstration Required. Primary Vehicle: Orbiter Alternate Vehicle: Spacelab. Installed Unit On Orbiter Could Establish Life Certification.	Certification Needed Prior To MSP
Catalytic Oxidizer	X	X	X	Ground Test Adequate For Certification	Zero-Gravity Demonstration Not Required	Certification Needed Prior To MSP
Electrolysis (SPE)			X	Safety And Functional Certification	Not Required, Use MSP For In-Flight Verification	Initial MSP Demonstrate With H_2O Supplied From Launched Tanks. Intermediate MSP Integrate With Sabatier & H_2O Reclamation For Life And Performance Verification.
CO_2 Reduction (Sabatier)			X	Safety And Functional Certification	Not Required, Use MSP For In-Flight Verification	Intermediate MSP Integrate With Electrolysis & CO_2 System For Life And Performance Verification.
O_2/N_2 Storage (Gas And Cryogenic)	X	X	X	N/A	Use Shuttle Certified Tanks On MSP	Certification Needed Prior To MSP

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Table 2.7.6.1.4-1 (continued)

FUNCTIONAL GROUP	MSP REQUIREMENTS			VERIFICATION LOGIC		
SUBSYSTEM	INITIAL	INTERMEDIATE	GROWTH	GROUND	SHUTTLE/SPACELAB	MSP
<u>WATER PROCESSING</u>						
Quality Monitoring	X	X	X	Safety And Functional Certification	Zero-Gravity Demonstration Required For Hygiene Water. Primary Vehicle--Spacelab Backup Vehicle--Orbiter	Verification Of Water Potability During Initial & Intermediate MSP.
Condensate Processing (Multifiltration)	X	X	X	Safety And Functional Certification	Zero-Gravity Demonstration Recommended. Demonstration Should Integrate With Condensing HX. Processed H_2O Can Be Stored In Existing Tanks For On-The-Ground Quality Evaluation Or Use Of Previously Demonstrated Quality Monitor	This Subsystem Provides Hand Wash Water On Initial MSP And Converts To The Posttreatment Section Of The Distillation Subsystem Used On The Intermediate & Growth MSP. Life Verifcation Is Possible During Initial Missions Since Product H_2O Used For Washing Only.
Wash Water (VCD/TIMES Distillation)		X	X	Safety And Functional Certification	Zero-Gravity Demonstration Required--May Integrate With Orbiter Hand Wash Or Shower Demonstration. Primary Vehicle--Orbiter	Life Certify On Early MSP. Should Be Integrated With Shower Or Clothes Washer For Adequate And Realistic H_2O Supply.
All Water (Urine, Wash Water, Condensate etc.) (VCD/TIMES Distillation)			X	Safety And Functional Certification	N/A See Above	Use Intermediate MSP To Verify Water Reclamation From Urine. Product H_2O Used For Washing Prior To Final Growth Step (Potable H_2O Production).

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Table 2.7.6.1.4-1 (continued)

FUNCTIONAL GROUP	MSP REQUIREMENTS			VERIFICATION LOGIC		
SUBSYSTEM	INITIAL	INTERMEDIATE	GROWTH	GROUND	SHUTTLE/SPACELAB	MSP
<u>HYGIENE</u>						
Hand Wash	X	X	X	N/A	Use Shuttle Certified Subsystem For MSP	Certification Needed Prior To MSP.
Shower		X	X	Safety And Functional Certification	Zero-G Demonstration Required. Primary Vehicle: Orbiter Due To Availability Of H_2O & Waste H_2O Storage.	Use Initial MSP For Life Verification And Integration With Wash Water Reclamation Subsystem Required For H_2O Supply.
Clothes Washer		X	X	Safety And Functional Certification	Zero-Gravity Demonstration Required. Primary Vehicle: Orbiter Due To Availability Of H_2O & Waste H_2O Storage. Alternate Vehicle: Spacelab	Use Initial MSP For Life Verification. Integrate With Wash Water Reclamation Subsystem For H_2O Supply.
Commode	X	X	X	N/A	Use Shuttle Certified Subsystem For MSP	Certification Needed Prior To MSP
Food Refrigerator/Freezer	X	X	X	Safety And Functional Certification	Zero-Gravity Demonstration Of Large Scale Units Required. Primary Vehicle: Spacelab	Certification Needed Prior To MSP
Oven/Galley	X	X	X	N/A	Use Shuttle Certified Subsystem For MSP	Certification Needed Prior To MSP
Trash Compactor	X	X	X	Safety And Functional Certification	Zero-Gravity Operation Demonstration Desired. Primary Vehicle: Spacelab; Alternate Vehicle: Initial MSP.	Initial MSP Can Use Shuttle Compactor. Intermediate MSP Requires More Capability.

Table 2.7.6.1.4-1 (continued)

FUNCTIONAL GROUP	MSP REQUIREMENTS			VERIFICATION LOGIC		
SUBSYSTEM	INITIAL	INTERMEDIATE	GROWTH	GROUND	SHUTTLE/SPACELAB	MSP
<u>MAINTENANCE DEMONSTRATIONS</u>						
Component Replacement (MDV's)	X	X	X	Life Cycle Test	Demonstration Required Primary Vehicle--Spacelab; Backup Vehicle--Orbiter	Capability To Replace Components & Subsystem Required Prior To Initial MSP.
O_2/H_2 Gas/Cryogenic Transfer	X	X	X	Safety And Functional Certification	Demonstrate Ability To Transfer Tanks Or Consumables Between Tanks	Capability To Transfer Consumables And Tanks Required For First Resupply.
Commode Transfer/ Maintenance	X	X	X	Safety And Functional Certification	Demonstrate Commode Transfer In Orbiter	Certification Needed Prior To MSP.
Logistics Plumbing Connections	X	X	X	Safety, Functional And Life Cycle Test Certification	Demonstrate Ability To Dock & Mate Logistics Plumbing	Reliable, Leak-Tight Plumbing Connections With Logistics Module Is Critical For MSP.

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Figure 2.7.7-1

DEPLOYABLE STRUCTURE TECHNOLOGY FLIGHT EXPERIMENT

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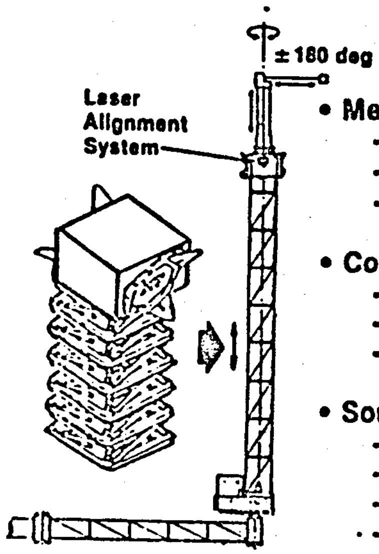
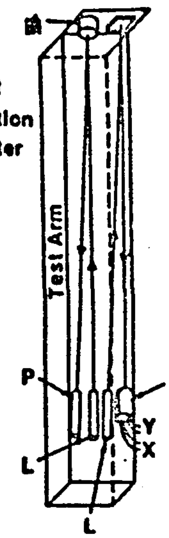


- Measurement of
  - Deflections
  - Distortions
  - Dynamics
- Correction of Above by
  - Actuation Systems
  - Stiffness Modifiers
  - Joint Rigidization
- Sources of Problem
  - Thermal Environment
  - Payload Slewing
  - Arm Indexing
  - Attitude Control Maneuvers
  - Truss Manufacturing Tolerances



P: Polarimeter
L: Laser
D: 2-Axis Linear Detector
M: Plane Mirror
M̂: Polarizing Mirror

Figure 2.7.7-2

ADVANCED SCIENCE AND APPLICATIONS SPACE PLATFORM CONCEPT

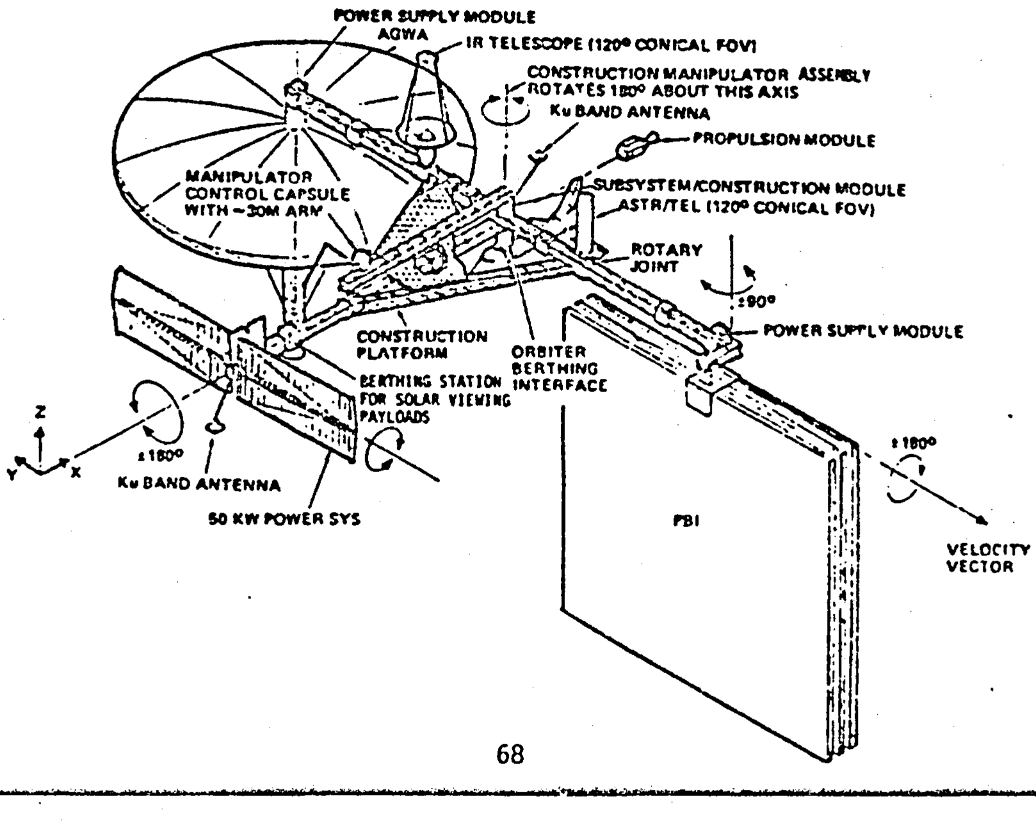


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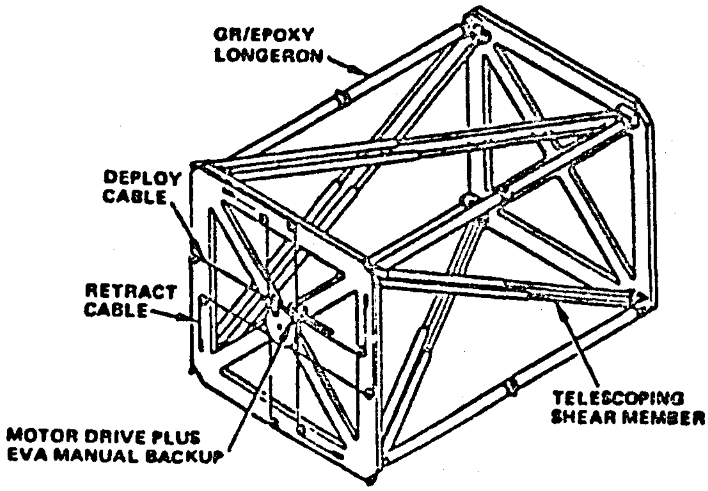
Figure 2.7.7-3
DEPLOYABLE TRUSS FOR COMPACTION IN CARGO BAY



- Mechanical Systems
  - Deployment techniques
  - Joints
  - Hinges
  - Actuators
- System Alignment
  - Pointing
  - Maneuvering
  - Surface measurement/alignment

It is the division of error among these elements that are almost impossible to model for assurance of design propriety. On-orbit tests must be performed with extensive instrumentation, such as the laser mentioned above, in a mode and installation much like an earth-bound structural test laboratory. The packaging of the type of experiment envisioned here (for the structure shown in Figure 2.7.7-1) to be Shuttle-delivered and later mounted on the manned platform for testing is shown in Figure 2.7.7-4. Note that this type of early development testing would precede the use of such structures in larger systems (later on the manned space platform) such as those described later in Paragraph 2.7.10, Large Multi-mirror Reflector Assembly/Alignment.

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Figure 2.7.7-4

DEPLOYABLE STRUCTURE DYNAMICS EXPERIMENT

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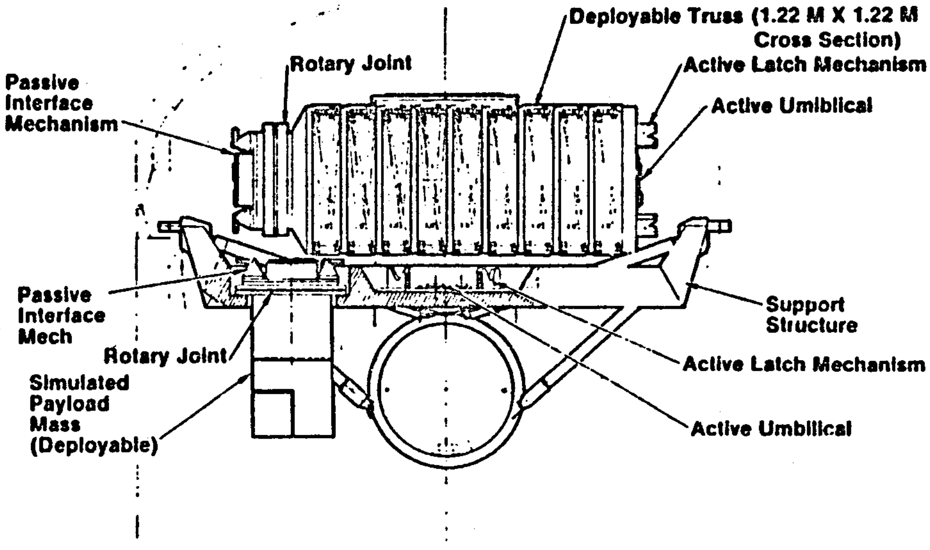

2.7.8 Propellant Handling Technology

The results of numerous studies have indicated potential advantages for operating an OTV from a manned orbital facility because extensive checkout and launch services could be made available and the desirability for economical reusability. This section discusses the evolution of the OTV technology needs and the utilization of the space platform to accomplish the technology experiments in early years of a manned space platform. Presented later in this report (in Paragraph 2.7.11) is a discussion of the operation of an OTV from the platform and the description of facilities required to support such an operation in the later years of the manned space platform.

The performance requirement for the OTV is such that large quantities of propellants are required to deliver the rather large payloads to high earth orbits. It is possible to build very large OTVs that use storable propellants to deliver the necessary impulse, however, the higher performance of the cryogenic propellant combination, LH_2/LO_2, makes this the more desirable propellant combination. A space-based OTV using cryogenic propellants requires a number of technological advancements before it can be successfully

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developed. Figure 2.7.8-1 depicts the evolution of cryogenic OTV technology development. A number of MDAC, MMC, BAC and RI studies and ground/flight experiments have led to theories and design concepts that indicate feasibility or value from an optimized, space-based OTV. These studies and ground experiments have led to concepts of experiments that could be conducted with the Space Shuttle. However, these experiments are limited in size and scope due to cargo bay space and on-orbit time limitation of the Space Shuttle. Therefore, these experiments have generally been designed to subscale sizes with the primary objective of demonstrating the concept. Before the design, manufacture and deployment of a space-based OTV fleet can be accomplished with confidence it is necessary to perform full scale experiments to verify the design approaches. The space platform very nicely provides the base from which large scale and long term testing can be done in the low-g on-orbit environment.

The technology needs for a space-based OTV as shown in Figure 2.7.8-2 are not limited to on-orbit development. The reusability and long term usage requires that the OTV reliability be very high and the maintainability be very simple.

Figure 2.7.8-1

EVOLUTION OF CRYOGENIC OTV TECHNOLOGY DEVELOPMENT

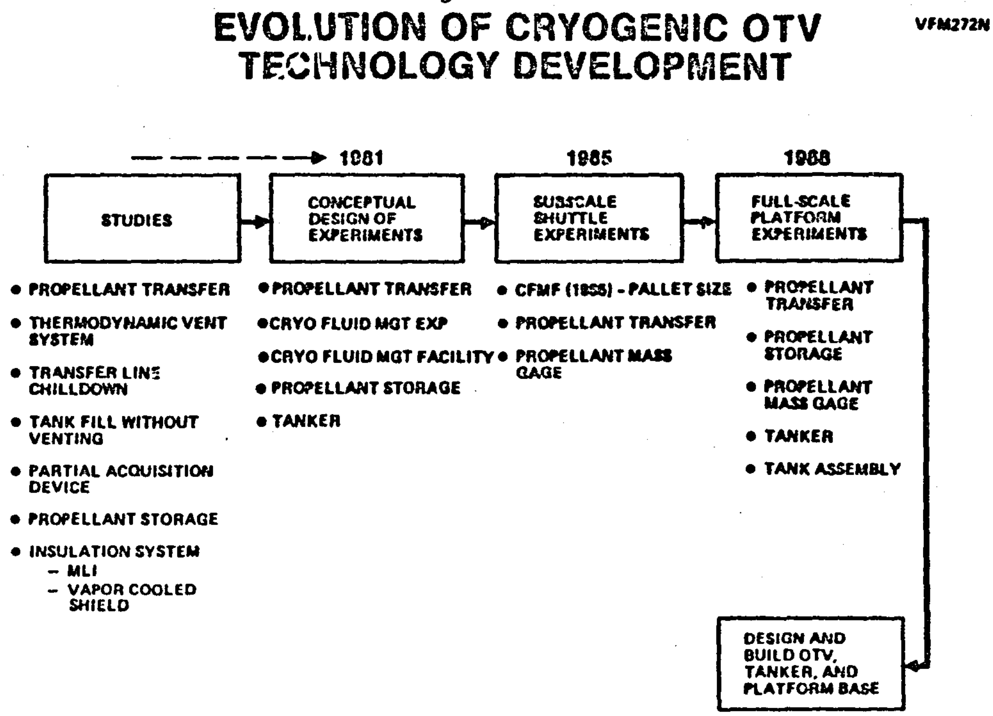

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Figure 2.7.8-2

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ORBIT-BASED OTV TECHNOLOGY NEEDS

- Propulsion Subsystem Must Include Additional Redundancy to Preclude Failures
- Electrically Powered Propellant Pumps
- Automated System C/O or Self-Checking
- Automated Launch Sequence With Minimum Data Output or Crew Support
- Long-Life OTV Engine and Multiple Reuse Without Refurbishment
- Leakfree Quick Disconnects
- Propellant Transfer
- Long-Term Cryogenic Propellant Storage
- Propellant Mass Gaging (Loading Accuracy)
- Modular Replaceable Units

Reliability enhancement can be accomplished by use of hardware whose reliability has been established by rigorous testing and by designing the various subsystems with additional redundancy. Ease of maintainability can be accomplished by designing subsystems into modular replaceable units. The checkout of the OTV and the launch sequence have to be automated in order to reduce the support needs of the platform crew. These technology needs do not require in-orbit testing to verify the design, however, the hardware must be designed for the low-g environment.

The development of an electrically powered propellant pump is dependent on the system concept selected for the OTV. That is, this technology is needed only if the OTV engines are pump fed. However, if the OTV engines are pressure fed, the most likely option although the pump fed system has better performance, this technology development is not required. The technology for long life and multiple reuse is currently being demonstrated on the Space Shuttle engines. However, these engines have the advantage of undergoing ground refurbishment after each use as the need arises. For the OTV engines, refurbishment will not be possible except when they are returned to earth. Therefore, they must be designed and rigorously tested to assure long-life capability.

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The OTV technology needs that require on-orbit demonstration and thus a space platform are the (1) propellant transfer, (2) long-term cryogenic propellant storage, (3) propellant mass gaging and (4) leak-free, quck disconnects. Figure 2.7.8-3 lists the type of experiments that could be conducted on the space platform to verify the design concepts related to the technology needs.

The propellant fill and drain experiment consists of a number of areas. The transfer line childown is critical because of possible overpressures due to boiloff of cryogenic fluids as it contacts the warm hardware. The chilldown of the propellant tanks require a significant quantity of liquid, therefore, it may be desirable to groudn chill the tanks and keep the tanks chilled throughout its on-orbit life. The propellant loading accuracy of the OTV has a direct effect on OTV performance capability because a 1% loading error translates into a six to 13% loss of payload capability.

The maintenance of chilled tanks and the long term storage of propellants require experiments that will characterize the performance of the OTV insulation

Figure 2.7.8-3

CRYOGENIC OTV EXPERIMENTS VFM271N

Propellant Fill and Drain
- Transfer Line Chilldown
- Tank Prechill (In-Orbit Chilldown vs Ground Chilldown)
- Tank Fill Without Venting
- Loading Accuracy
- Loading Times With Partial Acquisition Device on Tanker

Propellant Storage (Long-Term)
- Insulation — MLI vs MLI/VCS
- Zero-G Vent System

Tank Assembly
- Latching
- Umbilical Sealing

Monitoring and Maintenance

system. There are a number of insulation types and techniques available, therefore, detail analyses and actual testing to support the analyses and verify the design is required. Two typical insulation systems are all MLI and MLI/VCS. In order to successully store cryogenic fluids for long periods of time in the low g environment, a vent system that precludes liquid vent is required to minimize fluid loss.

Figure 2.7.8-4 illustrates a typical OTV technology experiment conducted on the space platform. In this particular case, the test objectives are (1) multiple tank assembly procedure and techniques, (2) propellant transfer from a storage tank to the OTV tank, (3) transfer line and tank chilldown and (4) long-term storage of cryogenic fluids to characterize the insulation system and verify the vent system design.

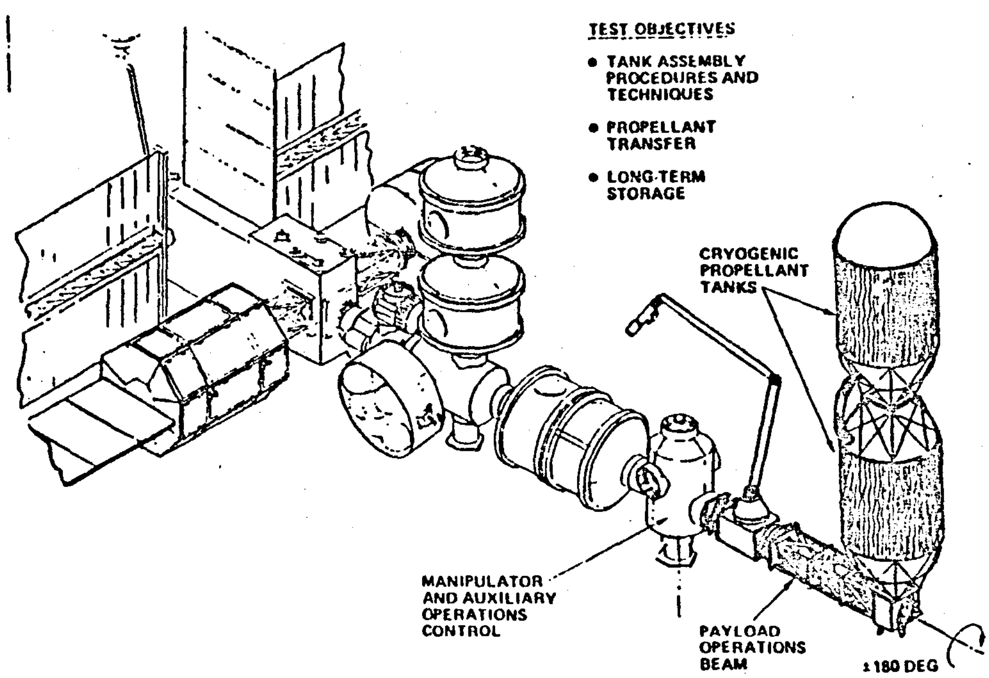
2.7.9 EVA and Remotely Controlled Servicing Technology

EVA is a mature technology and it can contribute much to the reliability and flexibility of the manned space platform and its payloads. Considerable

Figure 2.7.8-4

OTV TECHNOLOGY TESTING

VFM280N



equipment and tested techniques exist now but considerable development and on-orbit testing is required to prepare for major operational use of this valuable capability.

In the 15 years since the first EVAs in 1965 (23 minutes by Soviet Cosmonaut Leonov and 59 minutes by Gemini Astronaut White), major advances in EVA technology have been made. Pressure suit developments include increased mobility and dexterity, significant decreases in the energy required to maintain body position by the astronaut and improvements in suit life support systems. Airlock technology has been developed to eliminate the need for depressurizing the entire spacecraft prior to EVA. Major advances have been made in restraint and mobility aids as well as support equipment such as remote manipulators and astronaut maneuvering units.

Even prior to the first EVA, neutral buoyancy water immersion and parabolic aircraft flights were used to simulate the zero-g space condition but it was not until later Gemini, Apollo and Skylab flights that the true value of underwater simulation for EVA procedures testing and training became apparent. It has now become standard procedure to practice all EVA activities under water. The Johnson Space Center for instance has been performing simulations of Shuttle contingency EVA modes (e.g., payload bay door failure and thermal tile repair) and the Marshall Space Flight Center has performed extensive underwater simulations of Space Telescope on-orbit servicing.

EVA by the three Skylab crews, which transformed that mission from almost certain failure to an unqualified success, demonstrated the maturity of EVA as an acceptable way of achieving mission objectives.

On the manned space platform, the following types of functions can be substantially aided by the use of EVA:

- Large structure deployment
- Large structure assembly/alignment
- Film and tape replacement
- Focal plane instrument exchange
- Subsystem equipment exchange
- On-orbit checkout

- Experiment calibration/alignment
- On-orbit maintenance (scheduled and unscheduled)
- Payload deployment/retrieval/exchange
- Gas/cryogen replenishment
- Observation/inspection of experiments
- Contingency operations

Hopefully standardized techniques and equipment can be developed and utilized on many different payloads and platform subsystems. Certain techniques and equipment are of course available now but the scale of major future operations on the manned platform call for considerable new developments for the world of EVA.

EVA by the Skylab crew was a key to mission success. The difference between planned Skylab EVA (29 manhours in six EVA periods) and actual EVA (82.5 manhours in 10 EVA periods) illustrates not only the effectiveness of EVA but also its flexibility. Most of the 13 unplanned in-flight repair tasks were performed at locations where workstations had not been provided, to which preplanned translation paths were not available and at which crew and equipment restraints were non-existent.

Deployment of the O WS solar array and thermal shield, as well as installation of the rate gyro package, are dramatic in that failure to accomplish any one of them could have meant loss of the mission. Of almost equal significance, however, are the unplanned EVA tasks which saved numerous experiments from early failure and contributed to the scientific success of the mission.

The following EVA functions were performed on Skylab:

- Scheduled EVA - 29 manhours (six EVA periods)
  - ATM film retrieval
  - DO 24 sample retrieval
  - S230 collector retrieval
- Unscheduled EVA - 53.5 manhours (10 EVA periods)
  - Deploy OWS solar array
  - Deploy twin-pole thermal shield
  - Install rate gyro cable
  - Repair charger battery regulator module (CBRM)

- Repair S193 antenna
- Replace S082A film magazine
- Secure S054 and 5082A aperture door open
- Repair S054 filter wheel
- Clean S052 occulting disc
- Install and retrieve samples
- Install and retrieve S149 experiment
- Install, operate and retrieve T025, S020 and S201 experiments
- Remove S055, S056 and S082A ramp latches
- Obtain temperature of S020 experiment

- 18 extra mission objectives
- 13 in-flight repair tasks

EVA Equipment Available

The following equipment is available or under active development for use in the support of EVA.

A. Extravehicular Mobility Unit (EMU)

The Shuttle EMU is an anthropomorphic pressure suit containing its own back-mounted life support system. Compared with some earlier suits such as the Gemini suit, an umbilical is not required. A Liquid Cooled Ventilation Garment is worn under the basic pressure suit.

The Shuttle airlock, through which the EVA crewman exits and enters the Shuttle pressurized middeck, may be mounted inside the crew compartment or extenral in the payload bay attached to the forward bulkhead. Support equipment in the payload bay includes handrails for translating to various payload bay locations, lights, TV cameras and EVA tools.

Two EMUs are carried on each Shuttle flight. They will ordinarily be used by the Pilot and Mission Specialist, both of whom will have extensive training in EVA. The EMU can support six hours continuous EVA at an average metabolic rate of 1,000 BTU per hour. Suit pressure is nominally 4 psi and thus with a 14.7 psi Shuttle cabin prebreathing of approximately three hours is required. Following a six-hour EVA the suit can be recharged in one hour.

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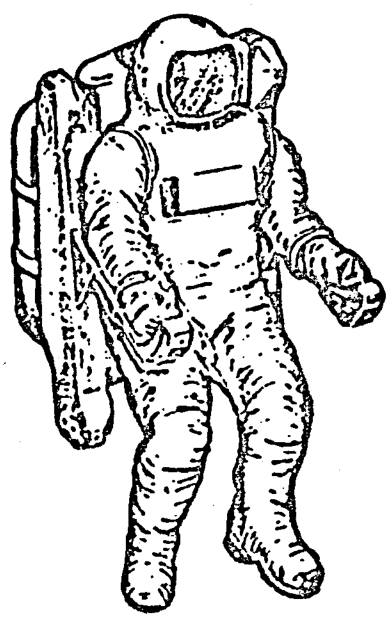
B. Manned Maneuvering Unit (MMU)

The MMU is a propulsive modular backpack device used with the Shuttle EMU to provide EVA working range and accessibility beyond the reach capabilities of the RMS. As illustrated and described in Figure 2.7.9-1 the MMU is designed to interface with the EMU and as such its continuous operating time is constrained by the six-hour per EVA limit of the EMU. To a large extent the EMU is a self-contained work station since it provides worksite lighting, outlets for power tools if needed and a capability for automatic attitude hold at the work station. However, if large forces and torques must be exerted at the work station, additional worksite restraints must be provided.

Figure 2.7.9-1

- **Development Status: Production**
- **Weight: 240 lb**
- **Propulsion: Noncontaminating Dry GN_2**
- **Control: 6 DOF Manual Translation and Rotation**
  Automatic Attitude Control
- **Power: 2-28 VDC Outlets**
- **Lighting: Two Spot Worklights**
- **Stowed in Payload Bay (X_o 582-636)**



MMU Donned

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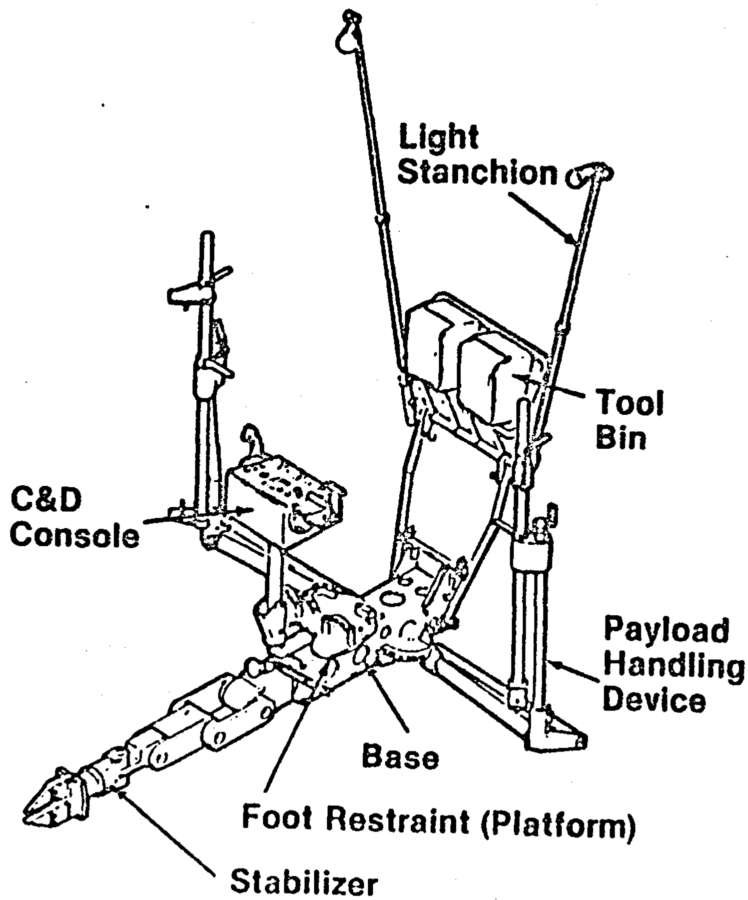
C. Open Cherry Picker MRWS

Manned Remote Workstation (MRWS) is a generic term for a family of manned work platforms, the first of which is the Open Cherry Picker (OCP) and includes closed work modules, railed work stations and free-flyer work stations. These future versions are planned primarily to support large space construction activities.

The OCP, illustrated in Figure 2.7.9-2, attaches to a standard RMS end effector and its work volume is therefore constrained by RMS reach. The EMU-suited crewman is restrained on the platform by a standard Shuttle foot restraint system. He operates the work station including the RMS itself, if desired, from a control and display

Figure 2.7.9-2
OPEN CHERRY PICKER MRWS



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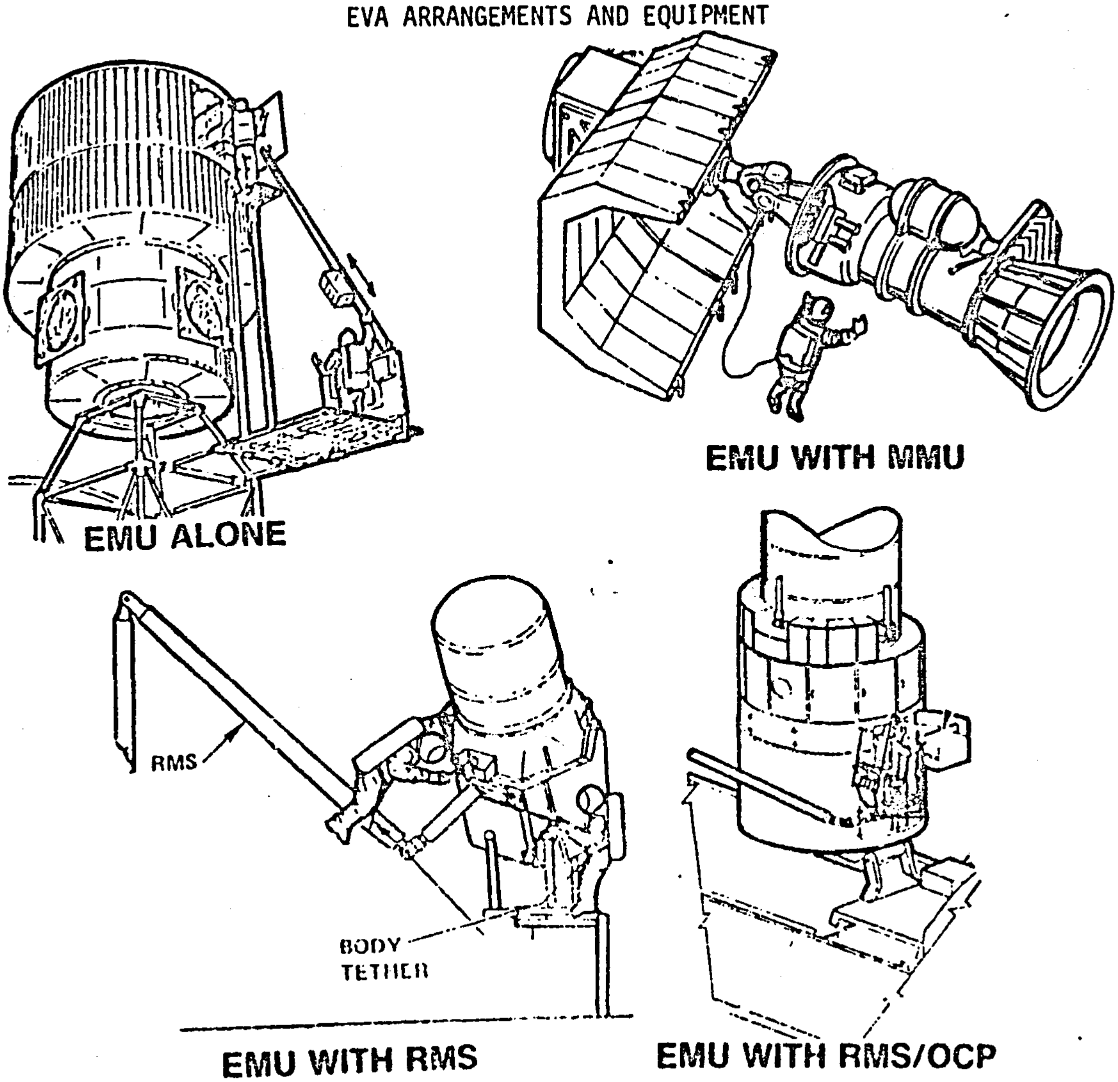
console located on the work station. The OCP work station is completely self-contained, providing electrical power via the RMS end effector, work site lighting, bins for EVA tools and a payload handling device for securing and transferring packages such as replacement instruments or subsystem components. An electro-mechanical manipulator (stabilizer) is provided to secure the OCP work platform to the work site.

Figure 2.7.9-3 illustrates various EVA arrangements in prospect for the emerging Shuttle/Manned Space Platform era.

Figure 2.7.9-3
EVA ARRANGEMENTS AND EQUIPMENT



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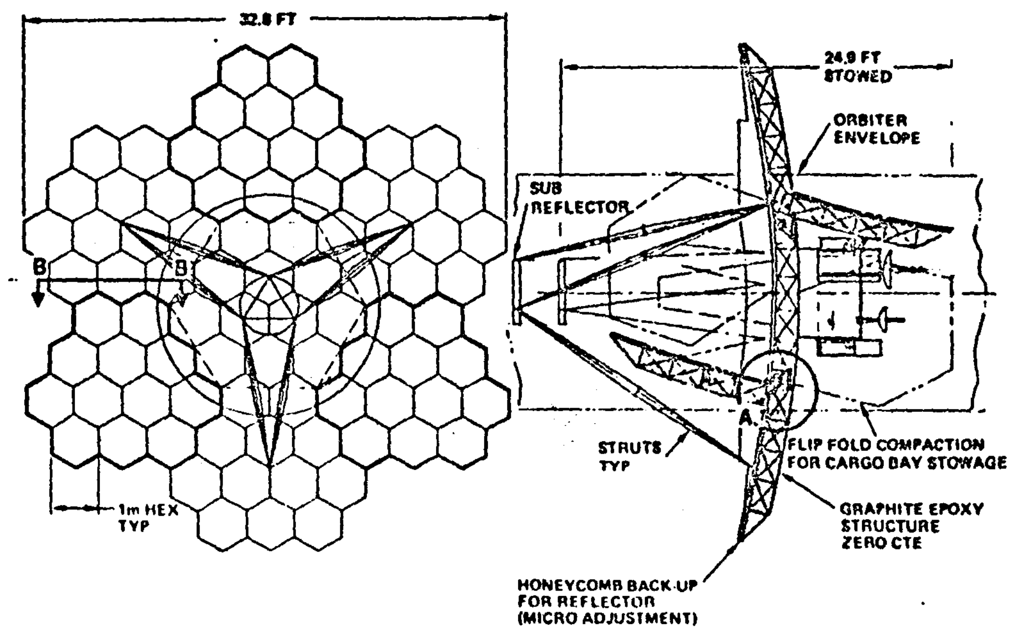
It is important to note that, as shown above, an RMS will most likely be mounted on the Manned Space Platform to support many payload support operations as well as aiding the loading and unloading of modules during Shuttle visits.

2.7.10 Large Multi-mirror Reflector Assembly/Alignment

Ames Research Center and the Jet Propulsion Laboratory are planning a 10- to 30-meter diameter, optical quality reflector spacecraft for infrared and submillimeter astronomy (Large Deployable Reflector (LDR) technology development plan; November 1981). Moreover, the DoD has great interest in these types of reflectors for IR and laser applications. Technology and study programs are currently aimed at a 1993 launch for a concept for alignment mounted on supporting trusswork. There is a possibility that such a capability could be compacted into the Shuttle cargo bay and deployed as shown in Figure 2.7.10-1, however, assembly of some elements in orbit is also a possibility. One contractor indicates that 12 meters diameter is the breakpoint in going from deployable to assembleable structures.

Figure 2.7.10-1

LARGE DEPLOYABLE ASTRONOMY REFLECTOR
(10m — 20m DIAMETER)
(INFRARED/SUBMILLIMETER)



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Regardless of the activation approach, an orbital base of some sort is needed and most likely one which flys much longer than the delivery vehicle, namely the Shuttle. Rigidization, alignment and checkout of this complexity-class type of spacecraft will most likely take on the order of many weeks, perhaps even months. The only reference point for estimating such operational time consumption is the "Six-pack," (six-segment) reflector of the University of Arizona Kitt Peak Observatory which has taken many months to align and particularly to understand the performance envelopes of the system under varying thermal loads.

In space, of course, this type of setup work is more challenging as is the environment and the cycling thereof. Therefore, although this type of spacecraft will fly unmanned in some particular orbit to satisfy its viewing objective, it requires a manned platform for activation and alignment as pictured in Figure 2.7.10-2.

Figure 2.7.10-2

LARGE MULTIMIRROR OPTICS SETUP AND ALIGNMENT

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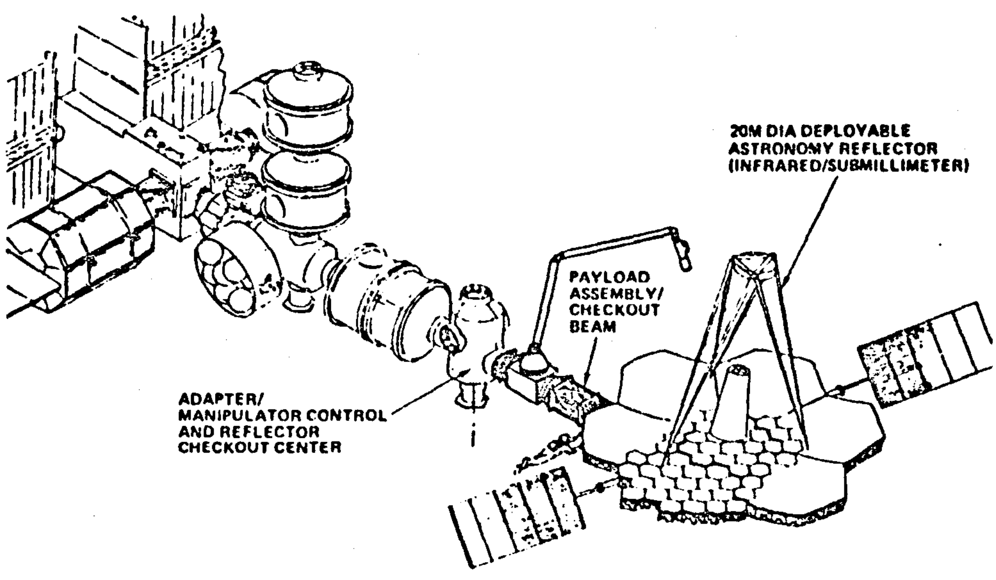

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The reasons for estimating on-orbit setup times of week, perhaps months, are listed in Figure 2.7.10-3 in terms of operations and structure challenges.

The very high number of parts and joints inherent in this class and size of configuration create a set of challenges which integrate a large variety of automated EVA and IVA functions. Although seemingly "crude" for the sophisticated systems involved, the practice of EVA volting of numerous critical joints appears a reasonable prospect here, since automated latches with sufficiently high-loading capacities would be prohibitively expensive and heavy. Moreover, the structural dynamicists advise us that analytical modelling and thus any substantiable prediction of on-orbit performance is barely feasible with highly-loaded bolted joints, let alone ones involving an automated mechanism.

Figure 2.7.10-3

LARGE OPTICAL-CLASS REFLECTOR PAYLOADS

Operations Challenges

- Set Up Berth, Power, and Command/Data Link
- Deployment, Assembly, or Hybrid Setup
- Support Structure Rigidization
- Thermal Stabilization/Compensation
- Figure Control Activation and Checkout
- Shape Measurement and Alignment (Partial/Total)
- Spacecraft Integration (Upper Stage If Required)
- Spacecraft Checkout and Launch
- Time Required: Probably Weeks Vs Days (Platform Vs Shuttle)

Structure Challenges

- Support Structures Must be Compactable Yet Rigidizable
- Compactable Structures Have Many Articulation Joints, Which are by Nature:
  - Free To Move In At Least One Axis
  - Difficult To Analyze/Predict As To Dynamics
  - Difficult To Solidify Rigidize
- Rigid Structures Require High-Load, Rigid Joints
- Bolted Joints (EVA) Probably Have Benefits Over Automatically Actuated Joints
  - Load Capability
  - Cost
  - Dynamics
  - Reliability

Therefore, although boling of joints seems an elemental function for astronauts it will provide a very important, cost-effective and most likely "only-way" service for high-accuracy large reflectors.

Figure 2.7.10-4 illustrates one concept for a joint in a substructure for the segmented mirrors on a large deployable reflector. Crew access is available for relatively simple tool bolt tightening after automatic deployment has taken place. The EVA functions necessary for this type of operation is only a nine-hour portion of each of eight days of an overall deployment timeline of some 30 work days estimated as shown in Figure 2.7.10-5. Although this is a seemingly long time for a relatively simple bolting function, there is structural dynamic theory behind the suggestion that there is nothing more effective or performance predictable than bolts for key parts of these complex structures.

Figure 2.7.10-4

EVA LOCK-BOLT INSTALLATION (DEPLOYABLE REFLECTOR)

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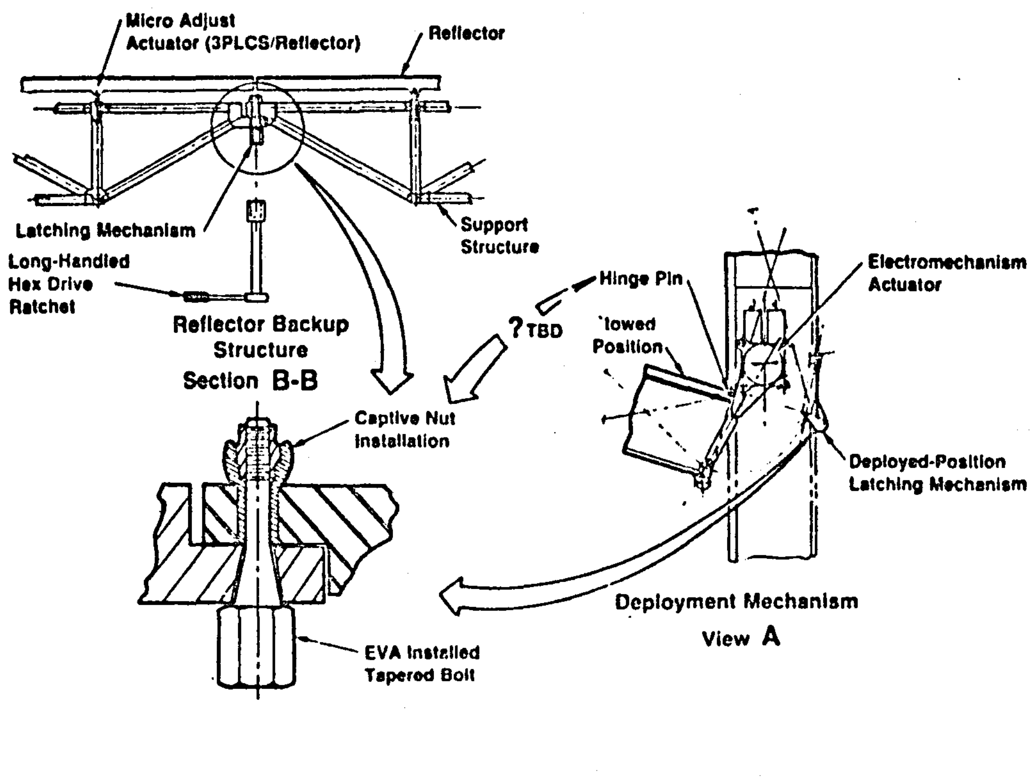

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Figure 2.7.10-5

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DEPLOYMENT TIMELINE
(10-M TO 20-M-DIA REFLECTOR)

Position For Deployment	5 Hr	~ 3 Days
Deploy Reflector Segments	4 Hr	
Crew Rest Period (Other Duties)	12 Hr	
Pre-EVA Preparation	1.6 Hr	
Prepare Equipment and Install 20 Attachments (1 EVA Shift)	6 Hr	
Post-EVA Activities	1.4 Hr	
Crew Rest Period	12 Hr	
Pre-EVA Preparation	1.6 Hr	
Install 32 Attachments and Inspect Total Assembly	6 Hr	
Post-EVA Activities	1.4 Hr	
Crew Rest Period	12 Hr	
Check Out and Verify Reflector Surface Alignment, Controls, and Spacecraft Subsystem Performance	20 Days (Details TBD)	
Final Checkout, Launch, Recheck, and Departure [EJECT FROM PLATFORM]	2 Days	
Total	30 Work Days	

The 20 days allocated for optical surface element alignment and other checkout assumes that considerable ground test and simulation have preceded the on-orbit activity and that the extent of deformations (not the nature or correction modes thereof) will be the only new phenomenon to be dealt with. Certainly the overall challenge of complexities here in prospect could increase on-orbit operations times significantly.

The sources of errors in segmented mirror surface contours in the space environment represent a composite of effects of ground manufacturing as well as on-orbit imposed variabilities, including deployment mechanism inaccuracies as well as the effects of thermal cycling and dynamic excitation impacts. Figure 2.7.10-6 illustrates these sources of error and Figure 2.7.10-7 illustrates one approach to measuring and controlling the onctours of the segmented mirrors as an integrated optical element. Here a laser scan of retroflectors distributed over the surfaces, creates error signals by virtue of computer comparison with an ideal model of the contour. Then appropriate commands are sent to actuators

Figure 2.7.10-6

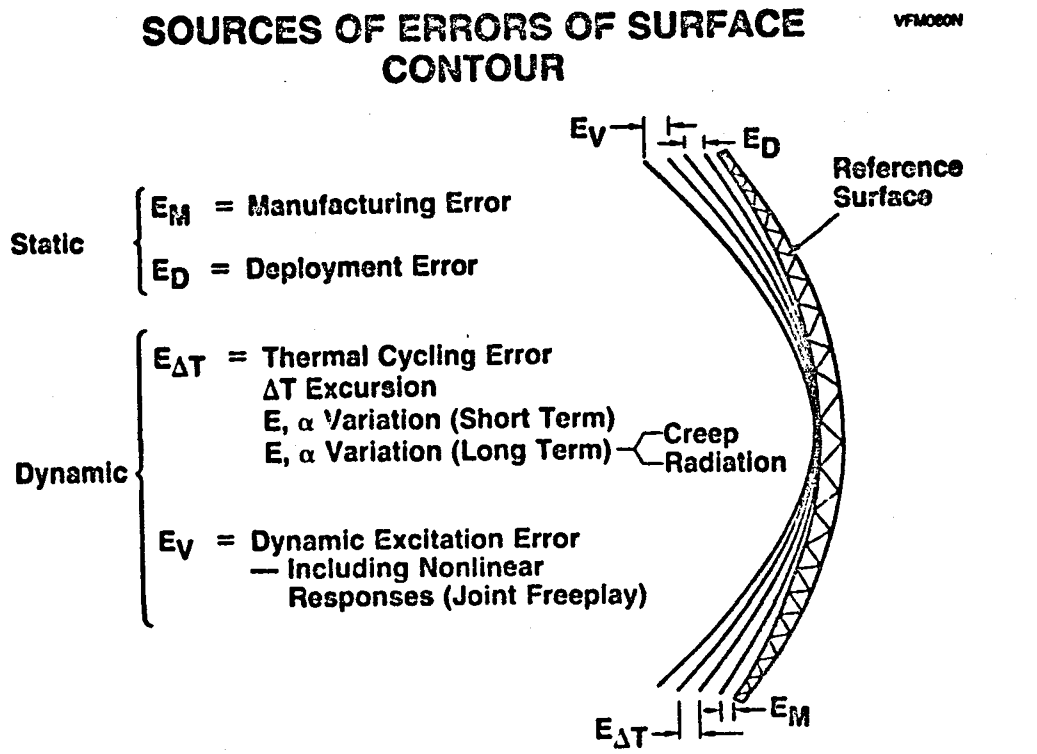
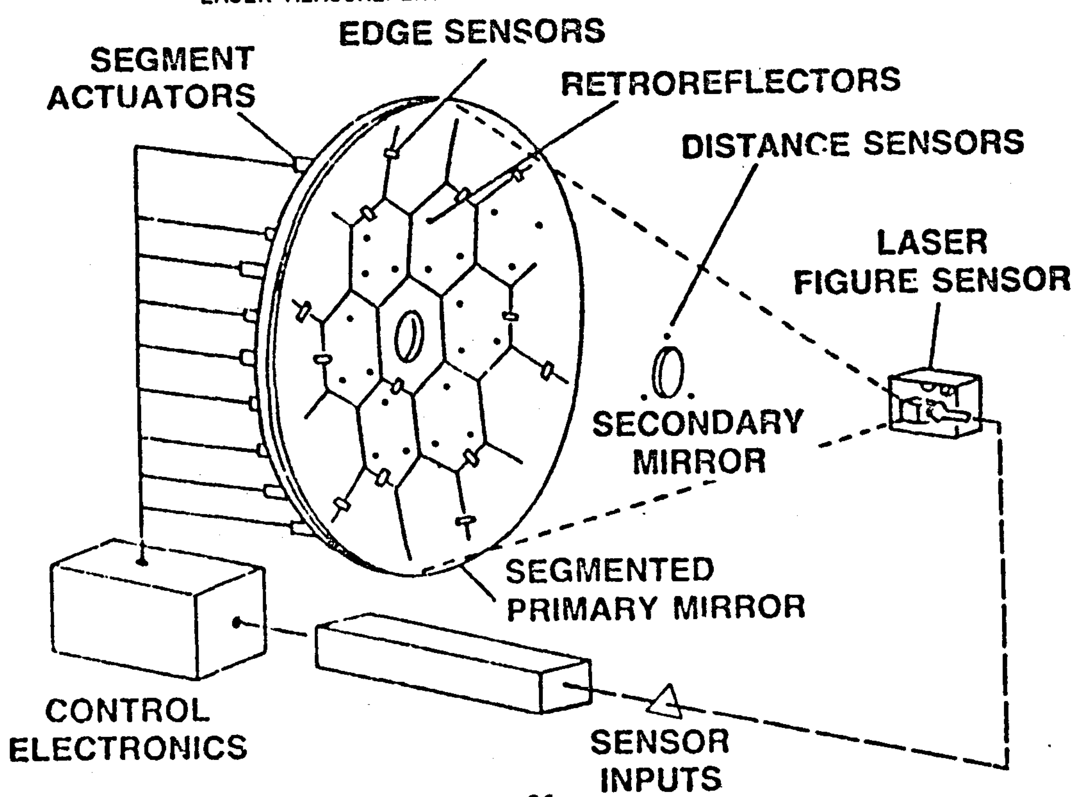


Figure 2.7.10-7

LASER MEASUREMENT OF REFLECTOR FORM/DYNAMICS



on the backs of the mirror segments to bring them into integrated alignment. As in the case of other highly-complex, future space operations, the program planned by NASA calls for early technology demonstrations in space to assure soundness of design approaches. Figure 2.7.10-8 shows (in the upper right hand corner) NASA's plan for such space tests of "certain" concepts which would constitute early experimental payloads on the manned platform in the late 1980s preceding eventual system activation in 1993.

2.7.11 Orbital Transfer Vehicle (OTV) Basing

The performance and utility of an OTV may be enhanced by operating it from a manned space platform. The many operations and facilities available to an OTV/platform combination are itemized in Figure 2.7.11-1. The platform provides the on-orbit base to which the Space Shuttle delivers the segments (i.e., multiple propellant tanks and propellants) of a large OTV in order to assemble an OTV capable of transferring large payloads to high earth orbit.

Figure 2.7.10-8
NASA PLAN FOR LARGE DEPLOYABLE REFLECTOR

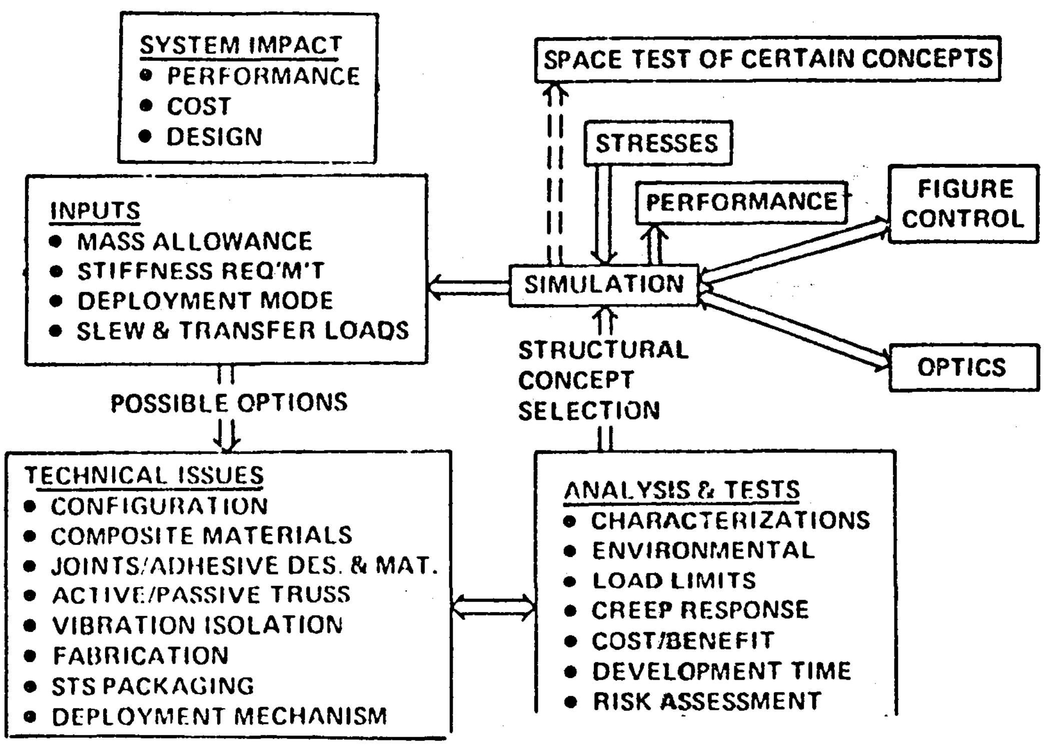


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Figure 2.7.11-1
OTV/PLATFORM OPERATIONS AND FACILITIES

VF0734

- Manipulation and Berthing of Large and or Multiple OTV Propellant Tanks and Payloads
- OTV (RE)Fueling
- Resupply Other Expendables (I.E., Gases, Batteries, Hydraulic Fluid)
- OTV Checkout — Maximize Self-Checking
- OTV Maintenance — Simple Functions Only

- Propellant Storage Transfer Tanks
- Propellant Transfer Equipment
- Pressurant Transfer Equipment
- Platform OTV Umbilical
- Checkout Console
- Checkout Support Equipment
- Control Center
- Remote Manipulator System for Payload Interchange

The platform provides a base for the OTV to be stored and resupplied. The resupply consists of propellants, gases and other expendables. The platform performs the checkout and maintenance of the OTV. The checkout is performed with facilities attached to the platform. The maintenance consists of simple functions such as replacing a modularized electronics box. Any complex repairs such as replacement of engines is performed on the ground unless the technology is developed in the future to safely perform these functions.

The following paragraphs describe the operating scenarios of the OTV and the facilities used to perform the launch, return and resupply of the OTV with the platform as a base.

A typical sequence for launching the OTV is illustrated in Figure 2.7.11-2. The sequence is OTV and payload checkout, payload installed on OTV, OTV separated from platform and OTV main engine fired after the OTV is a safe distance from the platform. The checkout and launch is performed by a crew stationed in a dedicated ORV test/launch module. The types of checkout and the facilities used to perform such a countdown and operation are described in the following paragraphs.

Figure 2.7.11-3 itemizes the checkout associated with the propulsion, thermal, mechanical, electrical and avionics subsystem. Because of the on-orbit limitations, there are several differences between the checkout on the platform and

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Figure 2.7.11-2

OTV OPERATING SCENARIO (LAUNCH SEQUENCE)

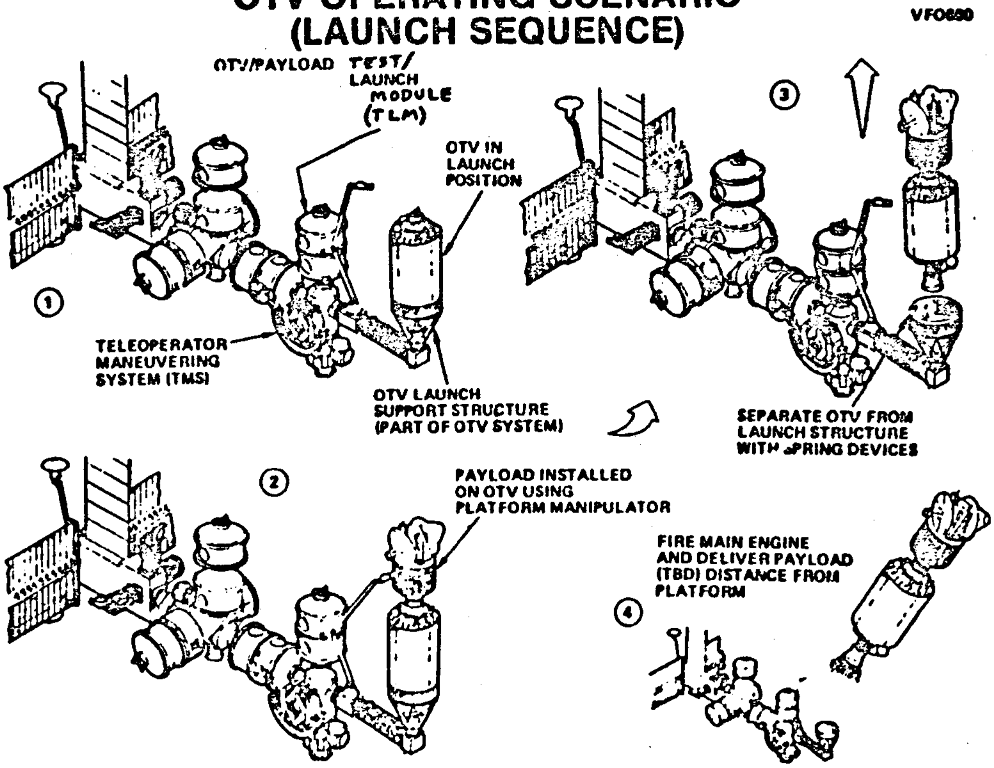


Figure 2.7.11-3

OTV CHECKOUT ON PLATFORM

VFO733

Subsystems

Propulsion
- Leak Checks
- Valve Functional Checks
- Instrumentation Calibration

Thermal
- Insulation
- Heaters

Mechanical
- Engine Gimbaling
- Berthing Mechanism — Separation
- Payload OTV Separation and Berthing

Electrical
- Power Subsystem Checkout
- Guidance and Navigation Subsystem
- Telemetry and Comm System

Avionics
- Data Management Subsystem
- Computer C O

How Different From Ground?

- Limited (or No) On-Line Replacement of Hardware
- Multiple Firing (Use of Cryogenic Engines with Minimum C O
- Limited Crew Size — Maximize Self-Checking and Computer C O
- On-Orbit Updating of Controls Software
- Limited Data Processing Capability
- Limited Power Resources
- Limited Capability For Cooling Electronics

the ground. These differences affect the design of the OTV and the platform facilities. For example, the small platform crew size means that the OTV checkout and launch operation should be automated to the maximum extent possible with backup support from earth-based crew.

Figure 2.7.11-4 defines the basic operational, safety and reliability interface requirements between the platform and the OTV. The design must establish communication links between the platform and the OTV, permitting the platform crew to control, monitor and evaluate the various systems of the OTV. Included among these activities are the operations required to verify proper platform/ OTV mating and interfaces; the operations needed to verify deployment readiness; the deployment operation; the post launch operations and the docking operations. These activities are controlled and monitored by a two-man crew and support equipment located in the test/launch module (TLM) shown in Figure 2.7.11-2. In addition, the OTV design must permit communication with the ground during post

Figure 2.7.11-4

STAGE/PLATFORM INTERFACE EQUIPMENT

VFO587

Requirements

- Provide Two-Way Command/Response Communication Between the Platform Systems and Crew and:
  - Stage Vehicle (Fly-Away)
  - Interface Equipment (Power, Propulsion, Mechanical, Electronic)
  - Fault Detection and Safing System
- Sequence and Manage all Predeployment Functional Activity
  - Propulsion System Preps
  - Mechanical Unlatch and Erection Systems
  - Stage Vehicle (Fly-Away) Preps
  - Spacecraft Preps (If Required)
  - Ready for Deployment
  - Guidance Update and Readiness
  - Power Systems
- Perform Fault Detection and Automatic Safing

Safety: No Two Equipment Failures or Operator Errors Shall Cause a Catastrophic Condition to Exist While in or Near the Platform

Reliability and Contingency Recovery

- System is Tolerant to Single-Point Failure
- Critical Power Systems Will be Redundant
- Crew Access to Critical Modularized Elements for Adjustment, Maintenance, Repair, or Replacement

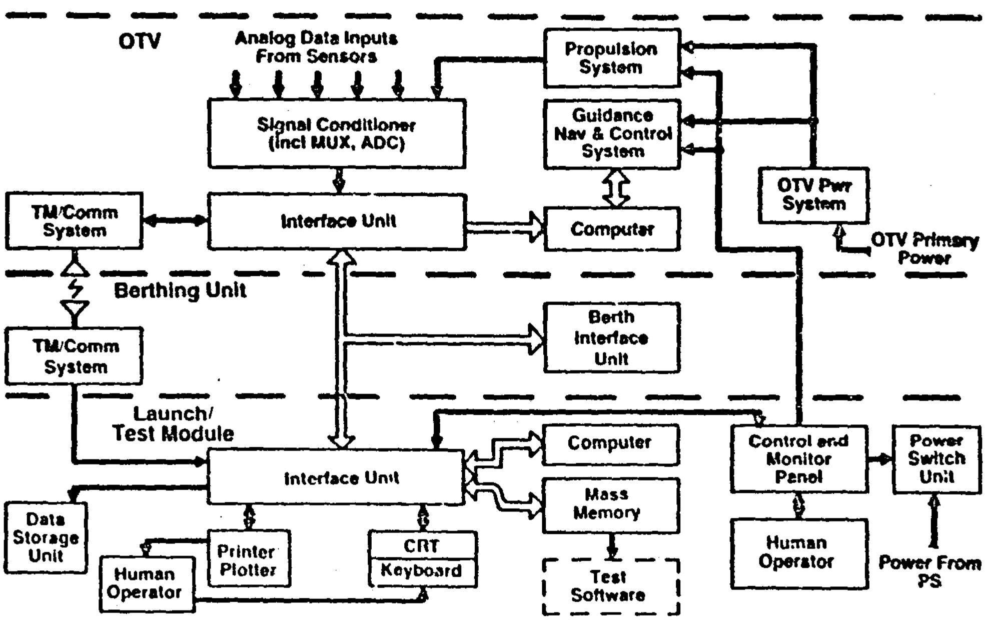
deployment operations. A block diagram indicating the major interfaces between the OTV, LTM and the connecting berthing unit is presented in Figure 2.7.11-5.

The basic OTV systems are shown including the propulsion system, guidance and navigation and control system, power system and telemetry and communication system. An interface unit, digital computer and signal conditioner unit complete the OTV avionics. The interface unit (IU) functions as a central data processor, controller and timing unit. It interfaces with the digital computer via a bidirectional parallel data bus; receives analog and digital data from the guidance and navigation sensors; receives OTV instrumentation and status data from the signal conditioner via a serial-digital data link; outputs control signals to the propulsion and vehicle control system; outputs serial-digital data to the telemetry/communications system for transmittal to the platform (after separation); and outputs serial-digital data to the LTM via a hardline data link (prior to separation). All data transmissions are coordinated by clock signals originating in the interface unit.

Figure 2.7.11-5

OTV/LAUNCH TEST MODULE AVIONICS AND INTERFACES

VF0731



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The OTV signal conditioner unit (SCU) accepts analog data from the OTV sensors (thermocouples, strain gauges, pressure transducers, etc.) plus bilevel status discretes from other OTV systems. The SCU then conditions and/or amplifies the data as required, time multiplexes the composite data, performs analog to digital data conversion, then outputs serial-digital data to the IU.

The guidance, navigation and control system (GN&C) contains the sensors required to detect changes in OTV body rates and attitudes. This data is provided to the onboard computer via the IU for computation of the control signals required to correct vehicle position and rates. The corrections are affected by varying the engine burn pulse rates and duty cycles of the attitude control engines.

In addition to containing the control system algorithms, the computer serves as the OTV timer. For example, the computer inhibits start of the OTV thruster engine until sufficient time expires for the OTV to achieve a safe distance from the platform.

The OTV power system includes a solar array affixed to the periphery of the vehicle surface plus storage batteries. The system also contains all equipment required to regulate, manage and distribute the available energy resources. Prior to separation from the platform, power is provided from the platform power system and controlled from the LTM. Subsequent to separation the power system is controlled from the ground via the communication system and the IU.

The telemetry/communication system (TCS) includes the transmitters, receivers and antennas required to communicate with the ground tracking station(s) and with the platform. It is anticipated that the primary command and telemetry link will be with the ground station(s) with the platform link required only during near vicinity (post deployment and predocking) operations. The communications links, operating in conjunction with the IU will provide the capability to control predetermined functions aboard the OTV including engine burns, power control switches, valve operation, etc. In addition, all data required to monitor and evaluate OTV performance and status will be transmitted to the ground and/or to the platform.

The test/launch module (TLM) includes the equipment required for control, test and monitoring of the OTV by the two-man crew. An interface unit similar in function to the unit in the OTV receives serial-digital data from the OTV. The data is displayed on the CRT and/or limit-checked by the LTM computer. Selected status data, including critical safe/arm functions are displayed permanently on the control and monitor panel. The crew also has the capability to control the OTV systems via the keyboard, interface unit and serial-digital data link. In addition, software and data is transferred from the TLM computer to the OTV computer in response to keyboard entered commands. The TLM computer, operating per the test software entered in the mass memory (magnetic disk or tapes) controls the automatic test routines required to functionally verify and evaluate the OTV systems. These test routines may be changed on-orbit by the crew entering new or revised software into memory. Permanent records of the test results may be recorded on the printer/plotter and/or the data storage unit. In addition to command and monitor capability of the OTV via the serial-digital data link described above, the crew also interfaces with the OTV systems through hardwires terminated at the control and monitor panel. These provide a permanent control and monitoring capability of functions critical to systems operation and crew safety.

Size estimates of the OTV test/launch support equipment are shown in Figure 2.7.11-6. Based on these estimates approximately five racks of equipment are required or one short module.

Table 2.7.11-1 itemizes the TLM/OTV checkout operations for each of the operational configurations. Due to the limited crew size, test complexities and limited available resources, the tests are automated as much as possible. In general, the tests consist of exercising one or more of the OTV systems per a program resident in the LTM computer and comparing the resultant data with predetermined limits, also in the computer. Audible and visible indicators alert the crew to unsatisfactory results and may result in termination of the program depending on the nature of the failure.

Figure 2.7.11-7 illustrates a typical OTV return sequence. In this example, a teleoperator maneuvering system (TMS) is used to retrieve the OTV. It is also possible to dock the OTV using cold gas jets located on the OTV for maneuvering.

Figure 2.7.11-6

SIZE ESTIMATES OF OTV LAUNCH/TEST MODULE EQUIPMENT

VF0728

	W × H × D (In.)
Interface Unit	20 × 20 × 40
Printer/Plotter	20 × 30 × 20
CRT/Keyboard	20 × 20 × 30
Computer	20 × 20 × 40
Mass Memory	20 × 20 × 40
Power Switch. Unit	20 × 10 × 20
Control & Monitor Panel	20 × 30 × 10
Data Storage Unit	20 × 40 × 30
Resupply Unit	20 × 20 × 30
Telemetry Unit	20 × 20 × 30
Rendezvous Radar Unit	20 × 20 × 40

Vertical Rack Available In Module = 650 In.

Therefore, OTV Equipment Requires Approximately 5 Racks or One Side of Short Module

Total Height of 20 In. Racks Reqd = 240 In.
+60 Contingency
300 In.

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Table 2.7.11-1

PLATFORM/OTV CHECKOUT OPERATIONS

VF0729

Postmate Checks of OTV With Launch/Test Module (LTM)

- Load Launch Test Module With Test Software
- Apply Test Power to OTV From Test Module
- Verify Communication Between OTV and LTM Computers (Auto Test)
- Limit Check OTV Instrumentation (Auto Test)
- Functional Test/Calibration of Guidance and Navigation System (Auto Test)
- Control System Verification (Auto Test)
- Propulsion System Checks
- RF System Checks (Manual Test)
- Power Transfer Check (Manual Test)
- Ordnance Systems Check (Manual Test)
- Simulated Launch Sequence Test (Auto/Manual Test)

Static Health Checks

- Minimum Power and System Operation
- Limit Checks By LTM Computer to Verify
  - Safe/Arm Status
  - Environmental Status
  - Power System Status

Prelaunch Checks

- Limit Check of OTV Instrumentation (Auto Test)
- Functional Test/Calib of GN&C System (Auto Test)
- Open-Loop RF Checks
- Simulated Launch Sequence Test (Auto/Manual)
- Transfer OTV To Internal Power
- Launch Sequence

Post Launch

- Maintain Communication Via Link
- Verify All Systems Normal Via Limit Check (Auto)
- Verify Normal Engine Start Sequence
- Monitor OTV Performance During Mission
- Record Data For Postmission Analysis

Predocking Checks

- Verify OTV Safe To Dock Via Auto Limit Check
- Monitor OTV Docking Sequence

Postdocking Checks

- Establish Hardline Comm Link Between LTM and OTV
- Transfer OTV To LTM Power
- Perform Functional Postmate Checks

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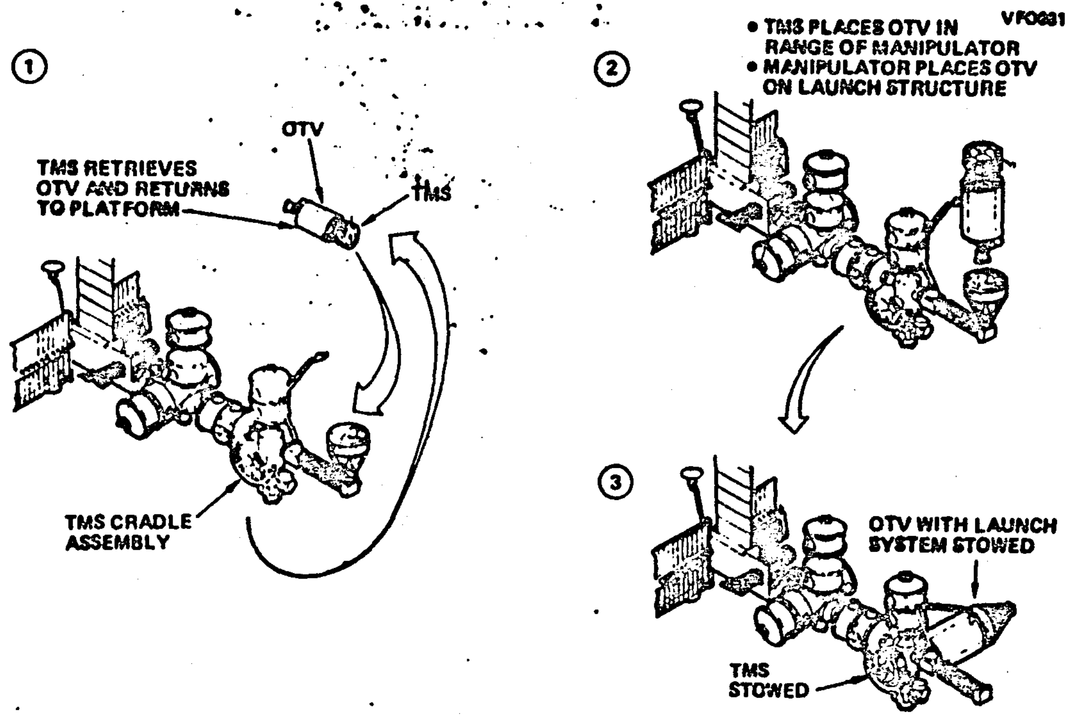
Figure 2.7.11-7
OTV OPERATION SCENARIO (RETURN SEQUENCE)



The TMS is used to position the OTV within the range of the manipulator system which does the final docking of the OTV to the platform. Before the OTV is retrieved, a full system shutdown and checkout of the OTV is made to verify that all hazardous systems are safe. A primary concern is the propellant containment and the propellant feed to the engines. Therefore, system redundancy and adequate instrumentation is required on the OTV to assure a safe OTV.

The next phase of OTV operation is the resupply of the OTV for its next mission. Figure 2.7.11-8 lists the options that are available for resupply, propellant transfer umbilical and propellant transfer method. The selection of a preferred method requires additional trade studies and engineering data from on-orbit subscale and full scale testing described earlier.

A typical propellant resupply sequence is illustrated in Figure 2.7.11-9. In this OTV operating scenario, the Space Shuttle transport the resupply

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Figure 2.7.11-8

OTV RESUPPLY CONSIDERATIONS

VFO738

Resupply Options

- Tanker Stays in Orbiter EVA Hookup Transfer Lines-Pressure Transfer
- ✓ Favored — Tanker Removed and Berthed to Platform-Pressure Transfer Through Berthing Interface
- Interchange OTVs

Transfer Umbilical

- OTV Design Same As Used 'n Orbiter For Ground Loading
- Tanker Location To Minimize Line Lengths
- OTV and Tanker Side of Interface Passive
- Active Portion Built Into Platform Design

Propellant Transfer

- Transfer Technique Depends on Type of Fuel Selected
- Cryogenic Fuel Will Require Special Passive Screen Devices to Accomplish Transfer
- Energy Addition, Depressurization, and Positive Expulsion Are Primary Transfer Considerations

Propellant Type

- Cryogen
  - Large Residual May Be Required
  - Chilldown Losses
  - Settling Force May Be Required
  - Losses Due to Extended On-Orbit Storage
- Storable
  - MMH/N_2O_4, ETC.
  - Transferable With Minimal Losses
  - State-of-the-Art Expulsion Technique

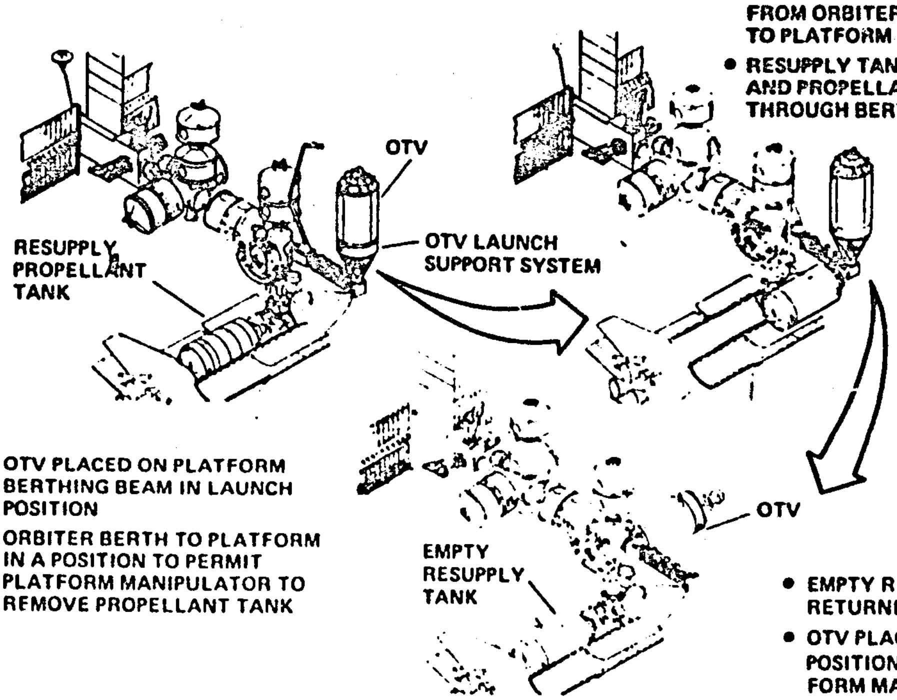
Problem Areas

- Propellant Selection
- Transfer System
- System Weight
- On-Orbit Handling of Large Stages

Figure 2.7.11-9

OTV OPERATING SCENARIO (PROPELLANT RESUPPLY SEQUENCE)

VFO726



- PROPELLANT TANK REMOVED FROM ORBITER AND BERTHED TO PLATFORM BEAM
- RESUPPLY TANK PRESSURIZED AND PROPELLANT TRANSFERRED THROUGH BERTHING PORT TO OTV

- OTV PLACED ON PLATFORM BERTHING BEAM IN LAUNCH POSITION
- ORBITER BERTH TO PLATFORM IN A POSITION TO PERMIT PLATFORM MANIPULATOR TO REMOVE PROPELLANT TANK

- EMPTY RESUPPLY TANK RETURNED TO OBITER
- OTV PLACED IN STOWED POSITION USING PLATFORM MANIPULATOR

propellant tank to the platform as required. A possible alternative is to transport and dock the resupply propellant tank to the platform so that the Space Shuttle is free to perform other missions. The resupply propellant tank is removed from the Shuttle and docked to the OTV launch support system for propellant transfer. This technique minimizes propellant transfer line lengths and the problems associated with transfer line chilldown. After the resupply is completed, the empty resupply tank is returned to the Space Shuttle and the OTV is ready for its next mission.

2.7.12 Spacecraft Servicing

In general, the primary justifications for on-orbit serviceability of spacecraft is derived from the extension of spacecraft life (repair of failed components), payload resupply or changes and spacecraft modification. Further, the repairability policy can be extended to include a preventive maintenance program via periodic on-orbit servicing.

Requirements for on-orbit serviceability can also arise from objectives not associated with the repair or prevention of failures. Periodic recovery of a spacecraft can be of great benefit to the payload program. Figure 2.7.12-1 describes the frequency of revisits which might be expected from requirements to update a primary optical sensor package, such as the type on a space telescope for example. In addition, other desirable changes which involve the qualification of new sensors, improvement of support subsystem components and mission modifications can also be implemented by recurrent servicing.

Figure 2.7.12-2 illustrates the prospect of a space telescope spacecraft which has been acquired and brought to the manned platform for servicing by a teleoperator maneuvering system.

The hardware changes planned for the servicing of (1) optic-based sensor payloads and (2) a highly-complex vehicle such as the space telescope will require considerable involvement of the crew on orbit supported by the Payload Operations Control Center. Calibration of several optical sensors and support elements could require considerable crew time which is of course the capability available on the manned platform. However, the operational impact of acquiring and bringing the spacecraft to be serviced to the manned platform is

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Figure 2.7.12-1

DUAL OBJECTIVES FOR ON-ORBIT SERVICING OF SPACECRAFT

VFO413

Spacecraft

Unplanned Contingency Repairs and Adjustment
Planned Preventive Maintenance

Payload (Example: Large Optical Sensor)

Experiment Change	Hardware Changes Required	Recurrence
Spectral Resolution of Optical Channels	– New Filters – Processing Electronics – Amplifiers	Once Every Two Years
Change Spectral Frequencies of Optical Channels	– Change Entire Optical Chains	Once Per Year
Change Number of Optical Channels	– Add Optical Chains – Add Detectors – Add processing Electronics – Modify Output Data Formats	Once Every Two Years
Improve Sensitivity of Measurements	*– Replace Detectors *– Add Supplementary Cooling Capability – Modify Detector Electronics – Modify Data Formats	Twice/Vehicle Life

*Could Be One or Both

Figure 2.7.12-2

SERVICING RETRIEVABLE SPACECRAFT

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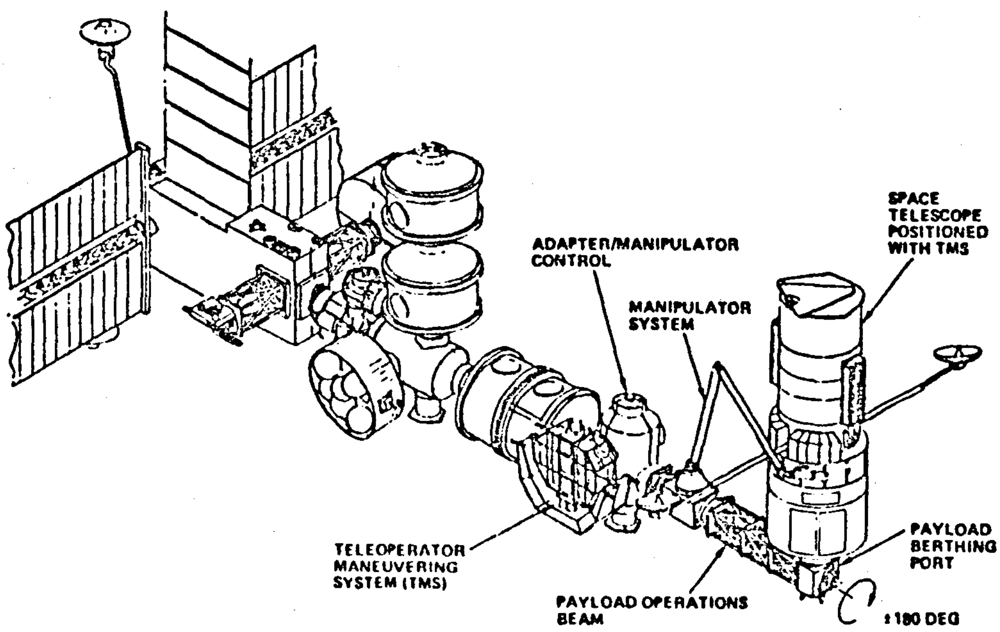

grossly estimated to be less than that of even 20% of a Shuttle flight (equivalent to payload servicing unit mounted in cargo bay) assuming reasonable co-manifesting of a Shuttle cargo load. However, the spacecraft to be serviced must of course be in an orbit location that is favorable to acquisition by a TMS based on a manned platform.

In basic fact, the primary justification for on-orbit servicing of spacecraft is increased cost effectivity and utility of the spacecraft. The servicing can be repair of failed elements, preventive maintenance to minimize failures, and/or modifications to change or improve features of the spacecraft. Considering these general approaches, on-orbit servicing can provide significant increase in the cost effectivity of the entire national space program. Future spacecraft specifically designed for on-orbit servicing capability will benefit the most, while earlier spacecraft will have to be evaluated individually to determine the feasibility and practicality of on-orbit servicing.

2.8 SYSTEM DESIGN GUIDELINES AND CRITERIA

Appendix C contains a 56-page compilation of detailed system design guidelines and criteria that were developed by MDAC over 20 years of contracts for NASA on studies and hardware (Skylab) of long-duration low earth orbit manned systems.

These were used as basic manned system requirements for the conceptual work in this study. They were compiled specifically for this study and were submitted to NASA/MSFC for review in August 1981 and revised in November 1981, based on NASA comments and in-house updates.

The information is divided into the following categories:

- Program General
- Platform General
- Interface Adapter/Airlock Module
- Habitability Module
- Logistics Module
- Subsystems
- Flight Support

2.9 MISSION ANALYSIS

The Mission Analysis effort included orbit selection and performance analyses of the Orbiter- MSP combination.

The orbit selection factors considered are shown in Figure 2.9-1. The primary influencing factors for inclination selection were mission requirement and payload capability; for altitude selection Orbiter payload capability and orbit decay. The initial orbit design selection envelope is shown in Figure 2.9-2. Inclination from ETR includes the 28.5 to 57° range, from WTR ≥70°. Those payloads not requiring a particular inclination (sensing, coverage, etc.) would probably be best accommodated at 28.5° because they could take greatest advantage of the planned Orbiter traffic. Support of geosynchronous bound missions would also be best accomplished from 28.5° because of the traffic, maximum Orbiter capability and minimum LEO to GEO velocity. Those missions requiring earth coverage or solar observation time would benefit from increased orbit inclination. A 50° orbit would allow coverage of the continental U.S., a 90° global coverage. Long term global coverage is reduced with

Figure 2.9-1

ORBIT SELECTION FACTORS

VFK586N

Mission Requirements

Payload Capability

Orbit Mechanics

Reboost Requirements/Capability

Lifetime/Contingency

Environment

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Figure 2.9-2

MISSION ACCOMMODATION/DESIGN ORBIT ENVELOPE

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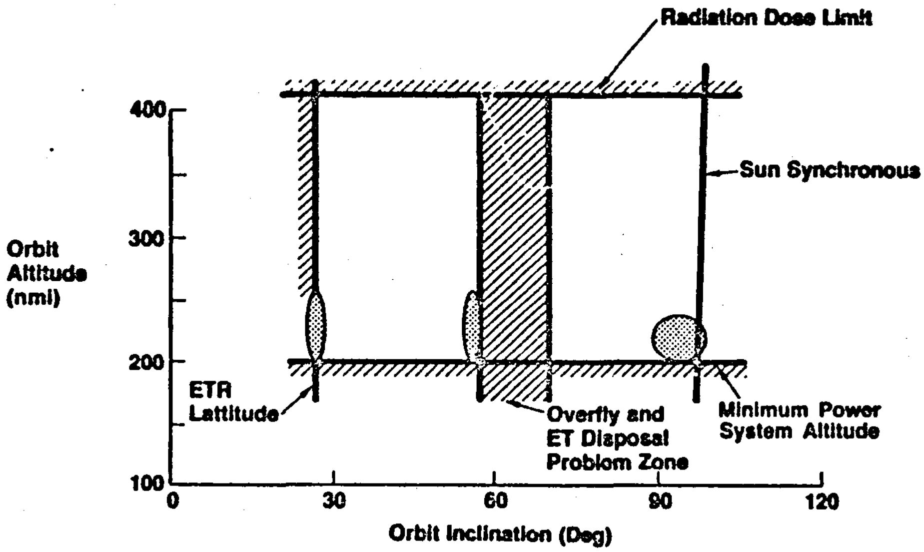

increasing inclination from a maximum at 28.5° to about 73% at 57° and 50% at 90° for altitudes commensurate with integral Orbiter OMS capability. Since the 57° capability of 40,000 lb from Figure 2.9-3 is adequate for the intended MSP launches a 57° orbit was selected since it would provide the desired coverage for Science and Applications Missions such as solar-terrestrial. As mission requirements mature in definition and funding other selections would be made. For example, 28.5° to serve the GEO bound missions and 90° for earth coverage mission. In any case the design of MSP for an ETR launch (28.5° to 57°) would not be effected. A polar mission configuration would tend to be reduced in size because of the reduced Orbiter payload and the more dedicated nature of the mission.

The altitude selection was based on net Orbiter performance and orbit lifetime. Figure 2.9-4 shows the Orbiter delivery capability as a function of altitude. The performance is relatively flat till 20+ nm and is then reduced by about 1000 lb/nm as the altitude increased beyond 200 nm. Since reboost propellant needed to negate the effects of aerodynamic drag is reduced with increasing altitude there is a maximum net payload capability altitude as shown in

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Figure 2.9-3

SHUTTLE PAYLOAD DELIVERED REVISIT MISSION

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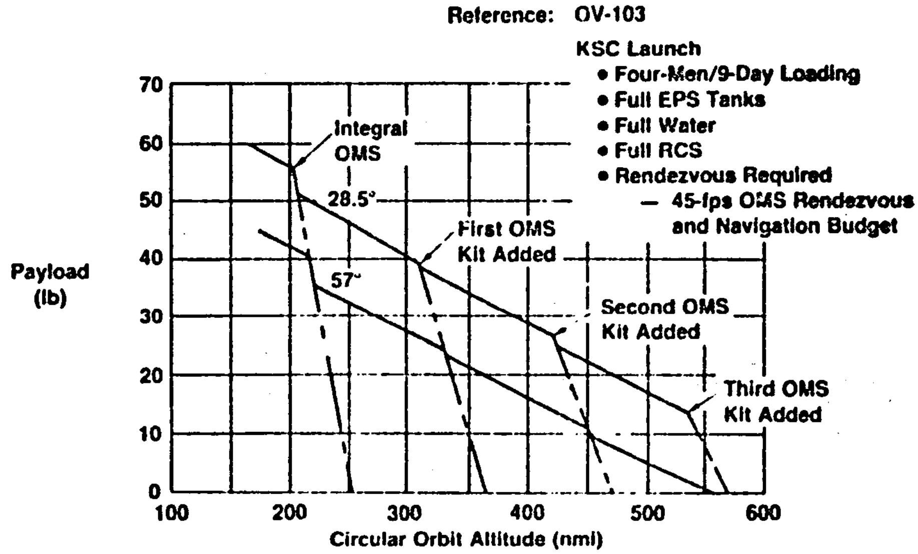

Figure 2.9-4

ORBITER PAYLOAD CAPABILITY POST 1984 ERA

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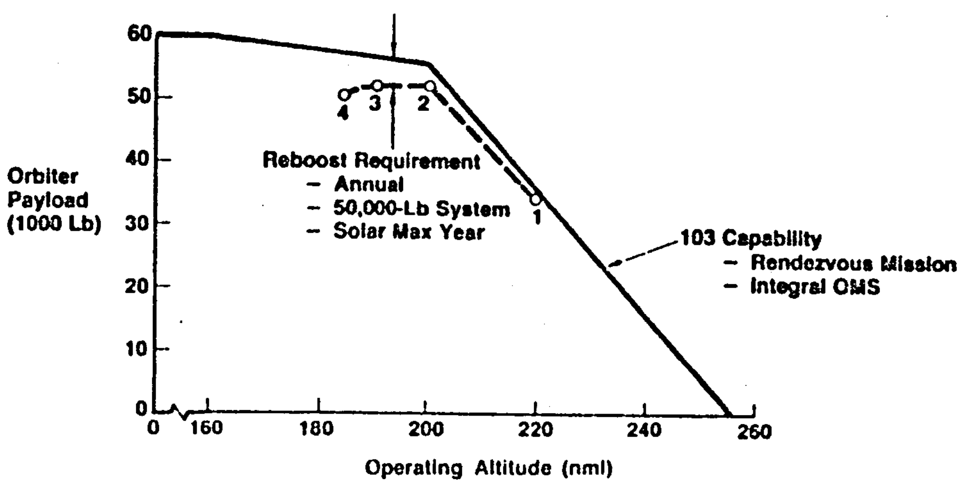

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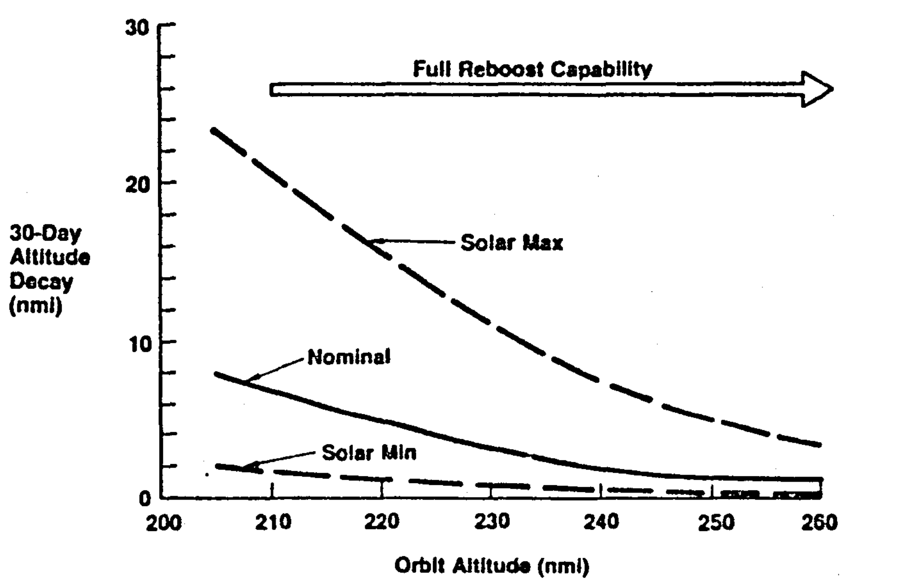
Figure 2.9-4. For the conditions shown for solar maximum activity and a one-year resupply increment the optimum altitude is about 200 nm. Also note that the net payload change with altitude is quite flat. This condition also holds for other conditions of orbit inclination, solar activity, vehicle mass and resupply frequency.

The orbit lifetime of the MSP is maintained by periodically reboosting as needed. Figure 2.9-5 shows the altitude decay over a 30-day period for various solar conditions and as a function of initial altitude. A more frequent reboost cycle would reduce the altitude excursion as needed. Consideration of the orbit lifetime in the event of the resupply vehicle (Orbiter) being incapacitated for some reason is important. The Skylab experience would like to be avoided if possible. In the event of forced abandonment, the MSP could be boosted about 50 nm in altitude by the onboard system assuming it was at capacity. From an initial 210 nm altitude this would allow a 30-day decay of less than 4 nm or a lifetime in excess of 8 months for a solar maximum condition and several years for a lesser solar activity (11-year cycle). Thus

Figure 2.9-5

ALTITUDE DECAY/REBOOST CAPABILITY
50,000 LB MSP



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a suggested orbit altitude of 215 nm was selected for study purposes. A final determination based on refined calculation of specific mission requirements (overfly, orbit repeats, resolution, etc.) and actual orbit contingencies that need to be considered.

The MSP mission will involve co-orbiting elements for purposes of extending the measurement baselines, presenting controlled targets for testing and periodic revisits for resupply or maintenance. The capability of the teleoperator maneuvering system from an orbiting MSP is shown in Figure 2.9-6. For example, the TMS can deliver a 10,000 lb payload to an altitude greater than 500 nm beyond the SAMSP orbit. Similarly the retrieval capability is large, for example, even a space telescope could be retrieved from its 320 nm orbit if need be.

The relative trajectory of potential co-orbiting elements is shown in Figure 2.9-7. As seen, the trajectory is dependent on initial deployment, relative drag (ballistic coefficient) and amount of periodic reboost applied.

Figure 2.9-6

TMS CAPABILITY ENVELOPE

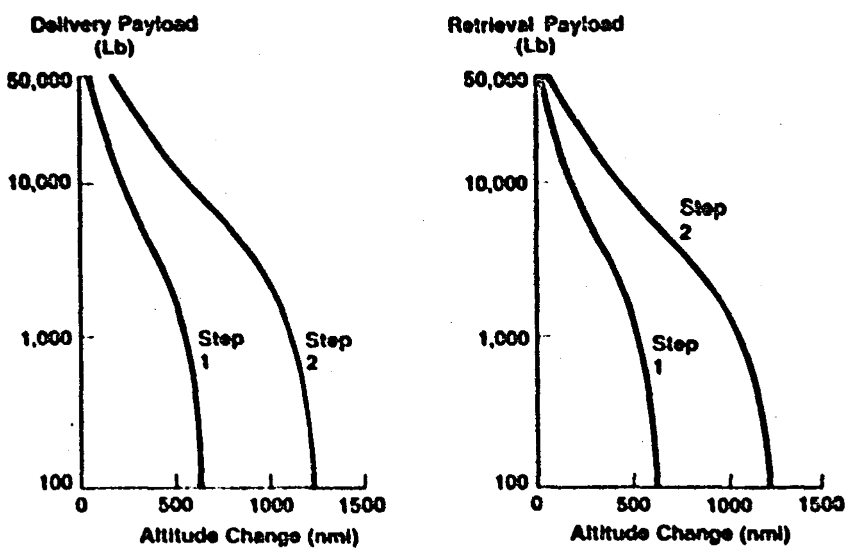

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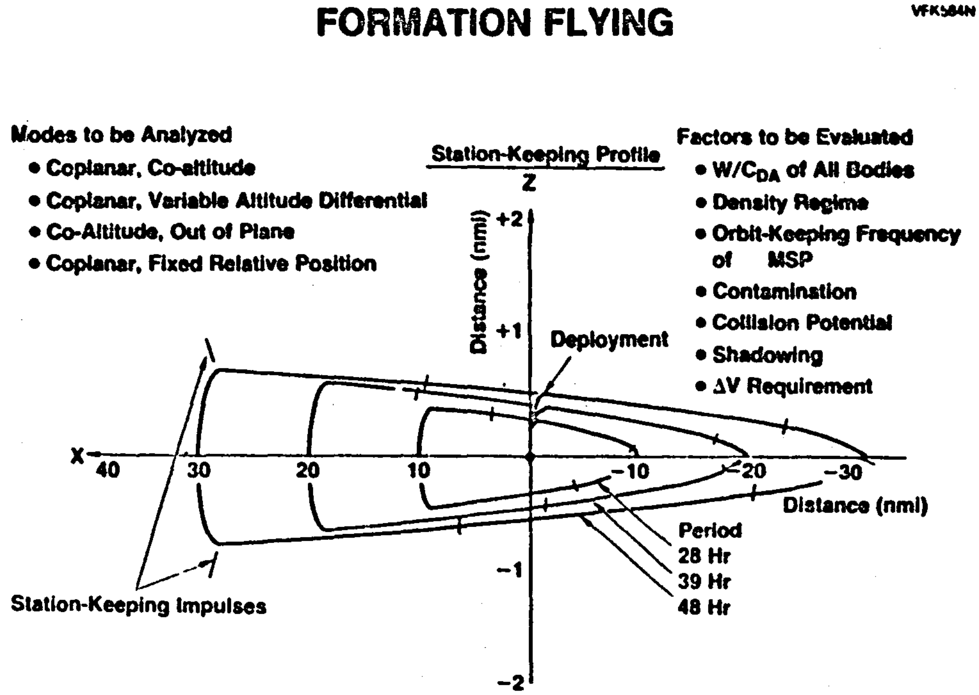
Figure 2.9-7

FORMATION FLYING



In any case the relative trajectory is far ahead and behind the SAMSP compared to its above/below excursions--on a ratio of about 60:1. This would influence the tracking, TM, pointing requirements placed on MSP.

The potential advent of a later more capable launch vehicle such as a Shuttle-derived vehicle (SDV) was considered. The payload would increase from the 65,000 lb class to the 146,000 lb class as shown in Figure 2.9-8. The volumetric envelope would be dramatically increased as shown. The major effect would be that an SDV-launched MSP would be configured to take advantage of the large diameters. Most of the elements would be reconfigured.

The analysis effort has resulted in the MSP summary requirements as shown in Figure 2.9-9. An IOC date of 1990 would be compatible with the growing demands of both Orbiter and Orbiter-Spacelab missions. The orbit selections made would be initial placement at 57° with follow-on activity at 28.5° and 90° as warranted by planned and budgeted mission payloads. Altitude selection would be in the range of 215 nm for ETR missions (28.5° to 57°) and under 200 nm for 90° missions.

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Figure 2.9-8

SHUTTLE-DERIVED VEHICLE POTENTIAL

VFM407N

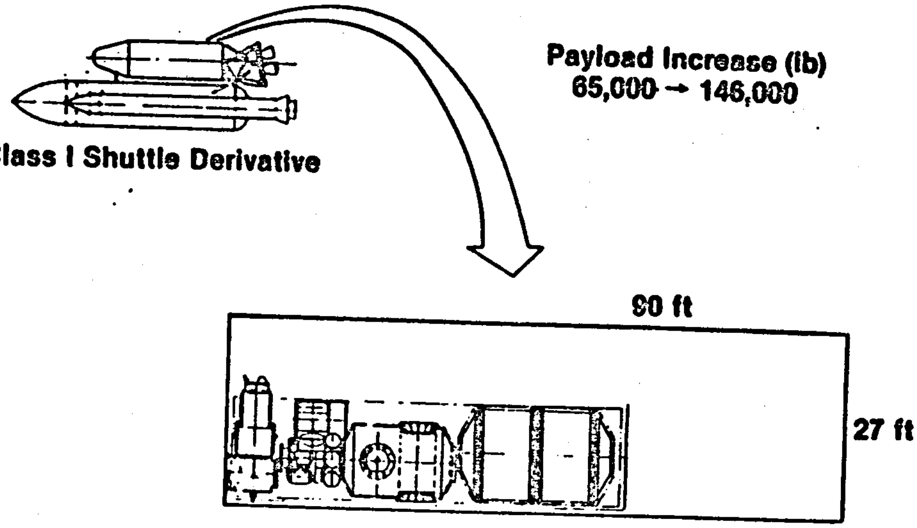

Figure 2.9-9

MSP SUMMARY REQUIREMENTS

VFM209N

- IOC — 1990
- Orbit Requirements
  - Inclination — 57 Deg → 28.5 Deg → Polar
  - Altitude — (200-400) 215 Nominal
- Evolving Capability

	1989	1990	1992
• Crew	2-3	3-4	5-6
• Pallets	2	3	5
• Modules	1-2	3-4	5-6

- Simultaneous Multiple Orientation — Solar, Earth, Low g
- Logistics Compatibility — Orbiter, TMS, Stages, Logistics Vehicle

Crew activity analysis has revealed that a two-man capability would be adequate for system activation with four men needed as a science and applications program would begin. The four men are needed to provide the skill mix, man-hour per day and two-shift operations that are required. Growth to additional crew would be needed as operational missions such as OTV support were added.

Simultaneous multiple viewing is needed from the outset to satisfy solar-terrestrial observations.

Section 3

CONCEPT IDENTIFICATION (TASK B.2)

Based on the requirements for payloads and interfacing systems plus the needs of man for sustenance and effective activity in space, the effort described in this section developed a number of basic concepts for a manned platform. Then an evaluation was made of the prospective features, benefits and constraints of each candidate concept, narrowing down to two for detailed system analysis and definition in the subsequent section (Section 4).

Figure 3-1 illustrates the intermediary nature of this subtask in this Phase A-type study. Here preliminary assessments were made of the potential advantages and disadvantages of using existing or advanced technology. Configuration, subsystems and operations specialists previewed options within their respective areas and then supported the identification of integrated concepts of merit.

A conceptual building-block approach was used to create concepts which fulfilled basic needs as well as progressively more ambitious payload and mission objectives.

By contract direction the Space Platform (Power System) was used as a packaged source for power, thermal control, communications and data management, attitude control and reboost propulsion. This unitized provision of such key resources was quite beneficial, as in the unmanned platform (SASP) configuration, because it could be conveniently installed on one end of the configuration to avoid interference with the many functions required for payload viewing, servicing, launching, retrieval and exchange operations.

3.1 CANDIDATE CONCEPTS

In order to shape and bound the activities in prospect for the manned platform, a profile of the complete spectrum of activities had to be defined. This included not only a great variety of interior and exterior payload operations but also the crew habitation and operations support functions, as

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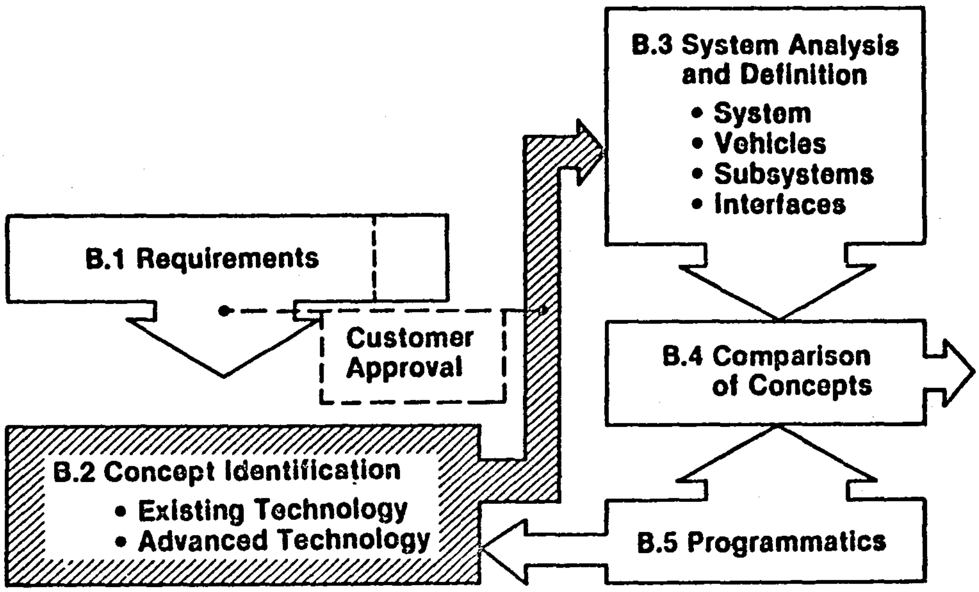
Figure 3-1

TASK B — MANNED PLATFORM CONCEPT



well as the initial activation and periodic Shuttle-based logistics visit functions that created significant interface considerations. Also, in view of a given reference Space Platform, specific interfaces and operating relationships were prescribed. Exterior operations would be substantial in number and would grow more complex through the years, which created significant forcing functions as to congregation or dispersal of functions and constraints on the size, shape and performances of vehicle elements involved or effected. Figure 3.1-1 lists the broad spectrum of activities which are inherent in the type of payloads in prospect and the type of platform required to fulfill such needs, the crew and interfacing accessories and systems.

Figure 3.1-1

MANNED PLATFORM ACTIVITY SPECTRUM

Interior

- Payload Operations
  - Life Science
  - Material Processing Applications
  - Technology (Habitation Enviromental Controls, Etc)
- Control Center(s) for:
  - Interior Operations
  - Exterior Operations
  - Exterior Payloads
- Habitation
- Maintenance/Logistics
- Traffic (Daily Routine and Logistics)

Exterior

- Attached Payload Operations
  - Solar-Terrestrial Instruments
  - Oceanographic Instruments
  - Large Space Systems
  - Development of:
    - Technology (Prototypes, Performance Measurement)
    - Operations (Assembly, Alignment, EVA)
    - Assembly Accessories
  - Geo-Vehicle Buildup/Stowage/Launch
  - Spacecraft Servicing
- Attached/Detached Payload Operations (Tended/Tethered/Teleoperatored)
  - Material-Processing
  - Experiments/Production
  - Free Flyers for Environmental Monitoring, Rendezvous Testing, Tow/Dock Services and Low-G Payloads
- Platform Sustaining Resource Installations
- Space Platform Interface
- Shuttle Interaction Operations

In order to develop a concept which effectively fulfills not only basic needs, but programmatic economies and growth goals as well, the various functions of the manned platform were congregated into modules, as shown in Figure 3.1-2. From past experience on Skylab and many NASA Space Station studies, much has been learned about the separate but complementary nature of certain congregated functions. In particular, basic subsystem functions, central buildup functions, habitation functions, logistics functions and payload functions are best modularized into separate entities for many reasons such as: packaging volume limits of the Shuttle cargo bay, RMS loading constraints, activity isolation, contingency retreat requirements, early-low-cost-minimal capability goals, payload exchange and mission scope growth plans, etc.

Since the size of the crew will most likely grow gradually from an early R&D activity level to eventual major operational activities, the habitats should

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Figure 3.1-2

REQUIREMENTS FULFILLMENT CONGREGATION
(HIGH-MODULARITY CONCEPT)

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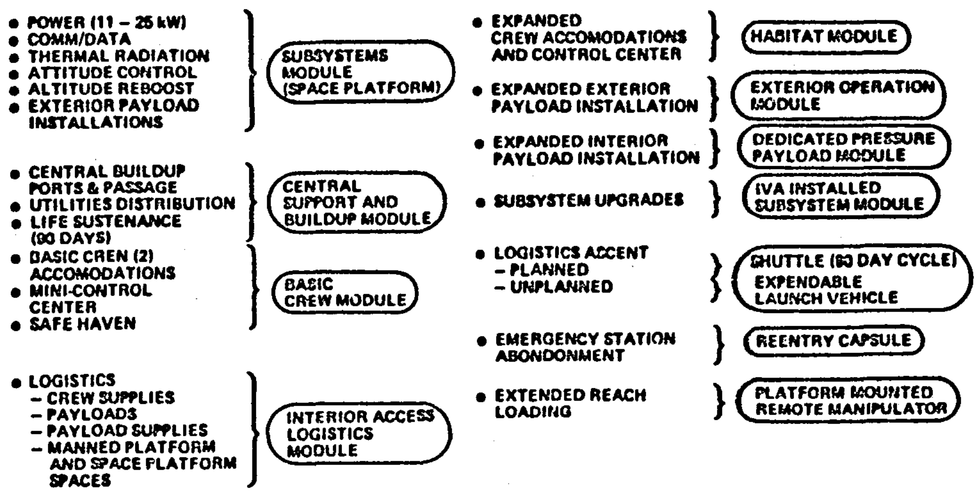

be small (two- to three-man) in size and replicated for growth. Payload modules, incorporating different dedicated payloads or shared mixes of payloads, should also be sized so as to permit great flexibility, i.e., probably the smaller the better.

Goals of upgrading subsystems through the years indicates the need for modularization at a "black box" level. The great increase in scope of exterior operations indicates modularity of increasing size to suit larger payload assembly and OTV and related propellant storage, payload assembly and launching. All of which indicate numerous berth or docking port requirements, multiple remote manipulators and above all, an effective plan for growth.

The study plan called for two basic modes of operation, namely Shuttle-tended and Free-Flyer. Figure 3.1-3 illustrates the vehicle options of escalating

Figure 3.1-3

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CANDIDATE CONFIGURATION BUILD UP CONCEPTS

	Vehicle Options					
	Shuttle-Tended		Free-Flyer			
Elements	A	B	C	D	E	F
Crew Size	2	3	2	3	4	6
Recycle Time (Days)	7-20	7-20	90-120	90-120	180	180
Spacelab Segments	2	3	2	3	4	6
Interior P/L Racks	16	24	10	16	16	24
Exterior P/L Installations	—	1	3	4	5	6
• Assy/Deploy	—	(1)	(1)	(1)	(1)	(2)
• Struct Control	—	—	(1)	(1)	(1)	(1)
• S/C Serv	—	—	(1)	(1)	(1)	(2)
• Subsat	—	—	—	(1)	(1)	(1)
• Geo-Staging	—	—	—	—	(1)	(2)
Growth Scenario Options	•		•		•	•
		•		•		•
			•		•	•
				•		•

capability, interior and exterior payload installations, mission support categories and logical growth step options. This chart was used as a skeleton on whith to build the design envelopes for the various modules seen to be needed for the initial and growth roles of the system.

Note that the initial crew size affects not only initial module sizing but also the potential and logical escalation step sizes. Therefore, it is extremely important to develop a plan for the crew size progression. In general, the plan which developed in this study, reflected an intent to establish a basic manned presence in space and to very gradually increase same. This plan was based on a philosophy which pervaded all study participants in NASA and MDAC, namely start small, and be flexible for growth even to large scope activities. This philosophy most likely was born not only of the general concern over available budgets in the time period of interest (late 80s), but also of the relatively selective nature of the early candidate payloads plus the sketchy nature and timing forecasts for the large scale operations such as large structure assembly and OTV basing.

As a sequel to congregating functions and assigning them to categorical modules, the elemental grouping of modules was mapped as shown in Figure 3.1-4. Reflected here are those constituents needed for a basic manned capability, an expansion thereof and major growth additions. Inherent in this modular map, therefore, are the berthing and subsystem interface functions created by the location and role of each module. Here then, we have the basic framework on which the evolving concepts will be based. Note that initial expansion is provided by adding a habitat module and an interior payload module. This is fundamental since the basic capability of the manned platform consists of long-term manned involvement in pallets of instruments as well as unmanned modules (i.e., pharmaceutical processing) mounted on the exterior of the vehicle. These payloads are most likely solar-terrestrial and MDAC electrophoresis pharmaceutical experiments flown earlier in the sortie mode for seven days on the Shuttle. The expansion

Figure 3.1-4

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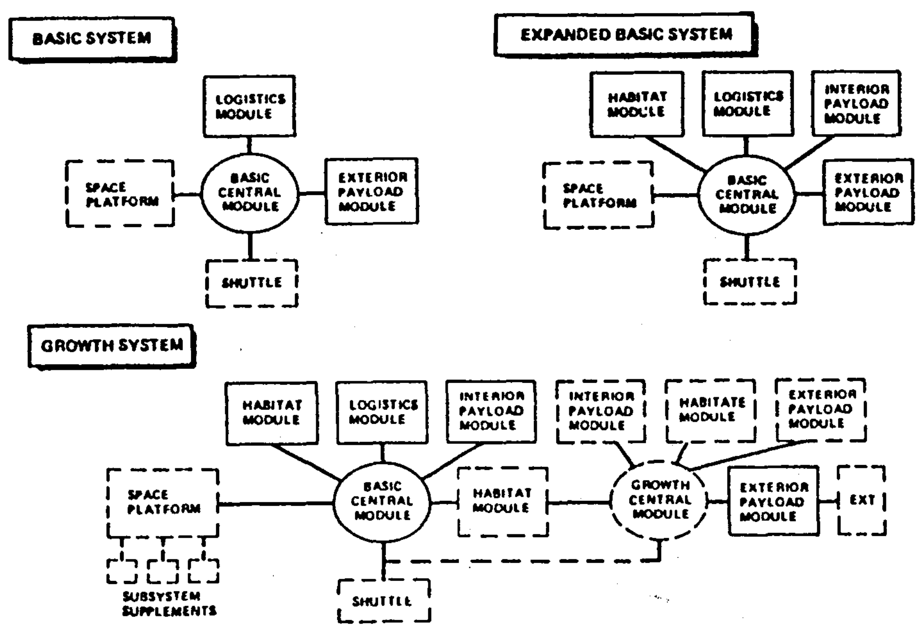
CONCEPT ELEMENTS AND GROUP GROWTH



addition of interior payloads is thus considered second in sequence because of the most probably dominant availability of exterior payloads in the early years. Broader growth is shown via the addition of a near replica (ideally) of the original basic central module, additional interior payload modules (now containing control centers for R&D testing or full-scale support operations for remote missions).

The size of the exterior payload module, envisioned as a beam of some sort (length, number of berth and umbilical types) is now increased, modularly, to handle larger size structures (reflectors, antennas), more vehicles such as OTVs, propellant storage facilities, payloads, etc.

Note that supplemental subsystem additions are schematically planned here for the Space Platform via the addition of more solar panels, radiator elements, batteries, CMGs, etc., to accommodate the greater resource needs of major operations in the later years of the manned platform.

3.2 CONCEPT CHARACTERISTICS

The next step in developing a configuration consisted of general shaping of the physical character of the modules mapped schematically in the preceding study process. Here, as shown in Figure 3.2-1, the provisions planned are divided into Basic and Growth categories. Payload accommodations are divided into habitat-shared as well as dedicated-internal and palletized-external. The payload (or habitat) module concept here began to take on the shape of the maximum diameter cylinder stowable in the Shuttle cargo bay, namely around 14 feet, which brings into candidacy the Spacelab segmented modules for consideration.

The Basic Central Module, which is shown to be a broad capability element of the configuration containing a safe haven (and with it the bathroom), major central docking ports and passageways and a mini-control center, not just for the Space Platform and Central Module combination, but also for a few pallets of experiments. Moreover, an airlock is considered to be a further necessary accessory to provide in one (and the first) module a mini-manned space platform capability, for interim periods, a few months that is, of residence, probably comfortably for two and in emergencies for four.

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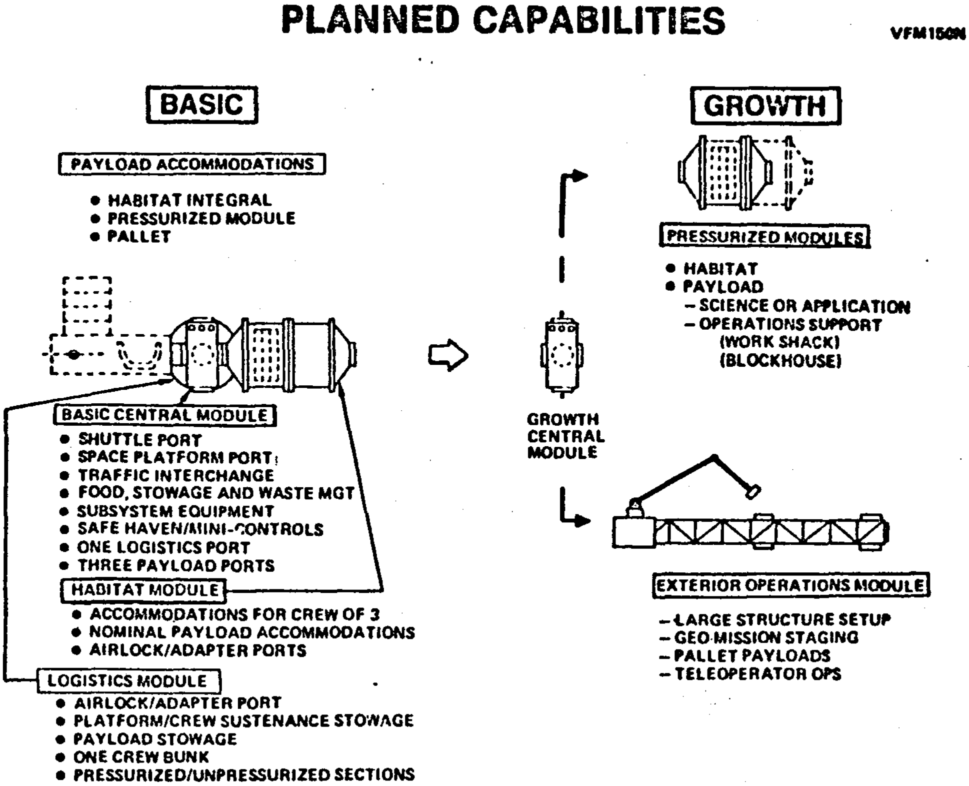
Figure 3.2-1

PLANNED CAPABILITIES



The Habitat Module adds a better class of crew accommodations and a supplemental number of payload racks.

The Logistics Module is seen to provide pressurized and unpressurized stores sections with the pressurized volume being in line for consideration as a maximum-diameter cargo bay unit, again conceivably a one- or two-segment Spacelab or U.S. mode if all new.

For Growth, a modified (simpler) version of the Basic Central Module should be possible; pressurized modules--like those used earlier--and a truss-like beam (similar to SASP because of similar berthing and service provisions) for the numerous and complex exterior mission operations anticipated.

Here then, the shape and fundamental character of each module is outlined conceptually. Exactly what they are like remains for subsequent steps.

With certain physical shapes in mind, various buildup options were defined as shown in Figure 3.2-2. Here, because of an early (later diminished) interest in a Shuttle-tended mode, coordinated buildup plans were developed for that as an introductory mode to the solo free-flying mode.

Envisioning crews of two to four and modest numbers of fully interior experiment buildups of one, two, three equivalent Spacelab segment modules were devised. Again, if not Spacelab units, then U.S. versions, but still of roughly the same dimensions because of modular freedom interests and relegation of the same cargo bay length for the simultaneous delivery of exterior (palletized) payloads.

Figure 3.2-2

EARLY SPACE STATION BUILDUP OPTIONS

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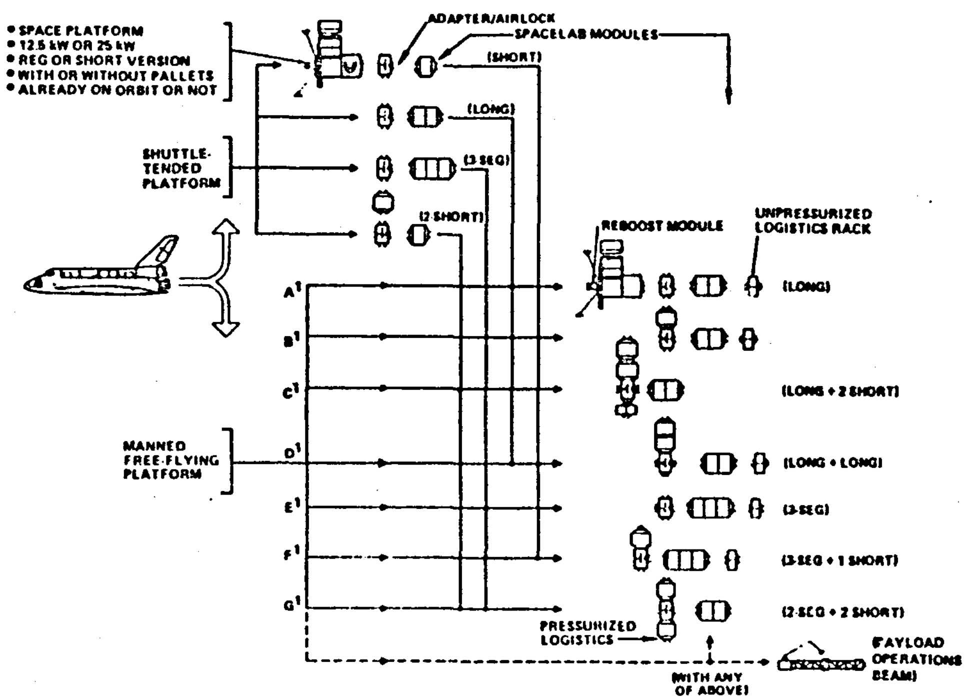

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More specifically, as to the character of the first and probably most important module, Figure 3.2-3 illustrates an open rack/center T-tunnel configuration approach to the Adapter/Airlock or Basic Central Module. A fundamental, low cost approach to supplying most basic needs. A similar approach is carried out in the Logistics Module with features described for both.

Figure 3.2-3

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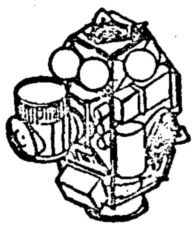
ADAPTER/AIRLOCK AND LOGISTICS RACK DESIGN CONSIDERATIONS

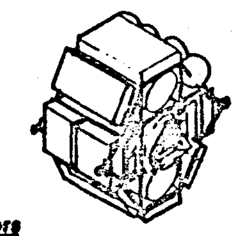
Adapter/Airlock



Factors

- Orbiter Interfaces
- Platform Interfaces
- EVA Activities
  - Planned and Unplanned
  - EVA Stay Time
  - No. of EVA Crewmen
- Use of Adapter as Emergency Shelter
- Crew Traffic Patterns

Logistics Rack



Factors

- Platform Resupply Cycles (Determines Volume of Expendables Required)
- Size and Weight
- Crew Access to Supplies
- Crew Safety
- Platform Interfaces
- EVA Access Vs IVA Access

A systems-level philosophy, developed at that time in the study, involved the concept of (1) an initial mini-capability manned platform via a single unit add-on to the Space Platform and (2) a safe haven/mini-control center, up initially, and ever after remains as the primary entry point and contingency retreat. Here then, more volumes and capabilities were called for compared to the approach shown earlier in Figure 3.2-3. Thus, Figure 3.2-4 illustrates the broader capability Basic Central Module. A higher capacity/volume Logistics Module is also shown based on the concept that resupply water, interior-type payloads and/or control units, food and possibly a field bunk-type crew quarters could be installed for a one-person added capability without the assembly of an entire new habitat to the configuration; a reasonable thought in a tight budget environment.

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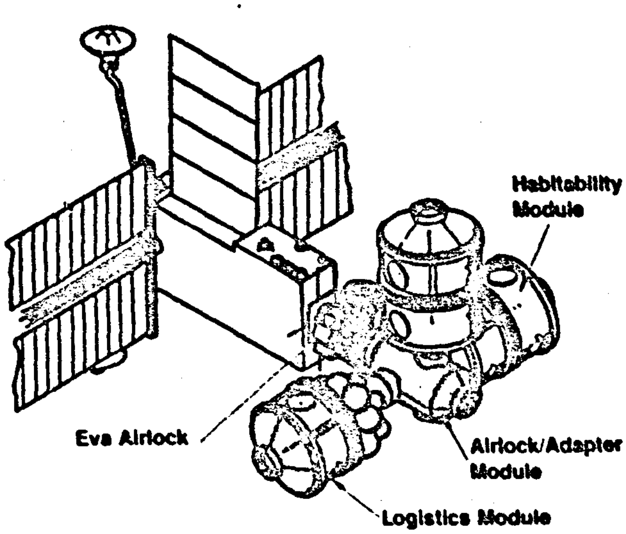
Figure 3.2-4

LARGE PRESSURE VOLUME CONCEPT FOR ADAPTER/AIRLOCK AND LOGISTICS MODULES



Adapter/Airlock Module

- Fair-Flow Cross-Passage
- Comfortable Safe Haven
- Mini-Control Center
- Mini-Two Man Station (SALYUT 6)
- Multi-Dock Ports
- Shuttle Airlock

Logistics Module

- Pressurized and Unpressurized Stowage
- Auxiliary Payload Operations or Field-Type Crew Quarters
- Convenient IVA Logistics

Therefore, an array of major elements were thus identified and grossly shaped and outfitted. Then it was possible to outline a number of candidate approaches as shown in Figure 3.2-5, including the important gradations in scale or scope of ultra-low, low- and medium-cost start options. Basically, the approaches coupled various types of central modules, habitats and logistics modules (the types having been described), a variety of cost-to-start options and some special features applicable to the main options. Recall that the central module options involved a rack/tunnel approach as well as one with greater pressurized volume. Also, the logistics module options were similar, minimal tunnel vs. significant pressurized volume. Recall further that habitats (and payload modules) could be 1-, 2- or 3-segment Spacelabs or U.S. built equivalents. The Exterior Payload Module (beam) was considered in any option to be a SASP derivative because of the considerable commonality of services provided and uses and, therefore, not added as an option, but as given. Three special feature options were also introduced at this time, namely (1) lateral expansion; i.e., parallel rather than normal to the solar arrays to probe possible cluster

Figure 3.2-5

VFR091

CANDIDATE APPROACHES TO SYSTEM EVOLUTION

25 kW Space Platform Plus:

1. ■ 3 Segment Modules ■ Aft Expansion
   ■ Integral Haven Habitat ■ Tunnel/Rack Adaptor
   ■ EVA/Umbilical/Rack and Modular Logistics
2. ■ 2 and 1 Segment Modules ■ Aft Expansion
   ■ Integral Haven/Adaptor ■ IVA/Umbilical/Modular Logistics
   ■ "Ultra-Low" Cost Start (2 Modules, Shuttle-Tended)
3. ■ Same as (2) Except "Low" Cost Start (3 Modules)
4. ■ Same as (2) Except "Medium" Cost Start (4 Modules)
5. ■ Special Feature: Lateral Expansion
6. ■ Special Feature: Emergency Crew Return
7. ■ Special Feature: Emergency Unmanned Logistics

advantages, (2) emergency crew return (same sort of reentry capsule), and (3) an unmanned logistics vehicle (akin to the USSR Progress vehicle which supports Salyut 6 frequently), but really conceived in the 1968 MDAC study for MSFC on the S-IVB Space Station.

Here then, are the candidates from which two are to be chosen for detailed study. General configurations of the assemblages represented in this array of approaches are shown in Figures 3.2-6 and 3.2-7.

A matrix of the features and sequential-capability growth is shown in Figure 3.2-8 as a format aid in evaluating the merits of each approach.

3.3 COMPARISON CRITERIA

The comparison of major vehicle configurations (born of different assumptions and approaches) as to effectiveness potential is a complex process involving

Figure 3.2-6

CANDIDATE EVOLUTIONARY APPROACHES

VFR077

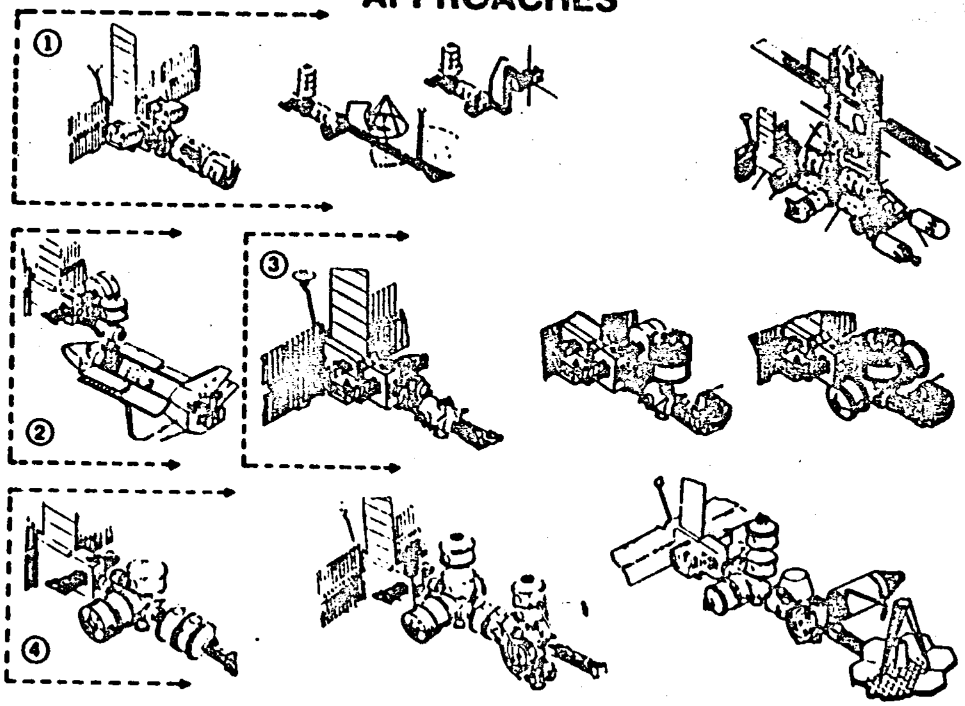


Figure 3.2-7

CANDIDATE EVOLUTIONARY APPROACHES (CONT)

VFR072

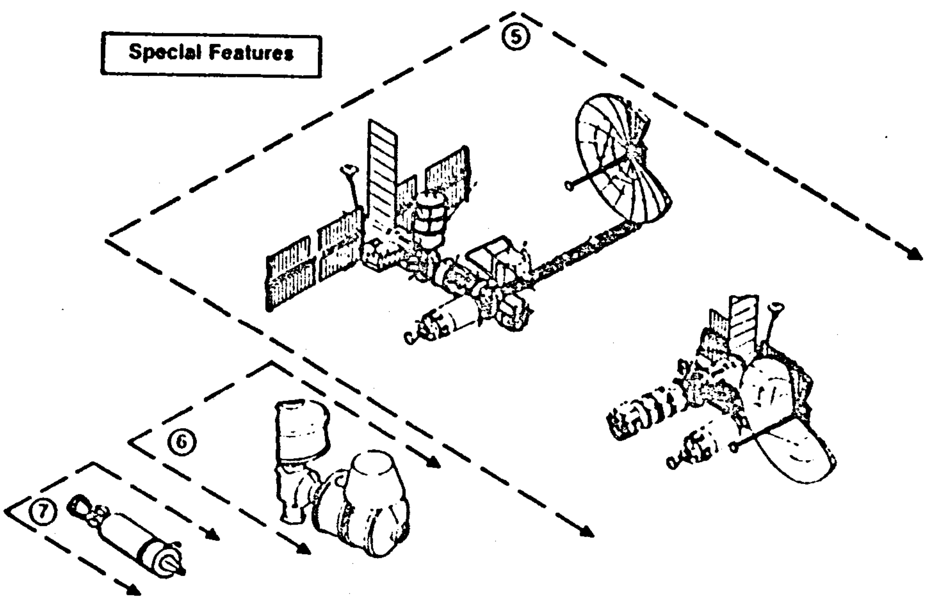


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Figure 3.2-8

CANDIDATE APPROACHES TO SYSTEM EVOLUTION

VFR078

(*SELECTED FOR DETAILED STUDY)

	APPROACH \ FEATURES	SHUTTLE FUNCTION	OPERATIONAL PHASE: ULTRA-BASIC INITIAL	OPERATIONAL PHASE: BASIC INITIAL	EXPANSION PHASES: I	EXPANSION PHASES: II	EXPANSION PHASES: III
① *	3 SEG MODULES/AFT EXP INTEGRAL HAVEN/HABITAT TUNNEL RACK ADAPTER EVA/UMBIL/MODUL LOGIST	DELIVERY REVISIT		HABITAT, ADAPTER AND LOGISTICS MODULES	ADD HABITAT & EXT OPS MODULES	ADD GEO STAGING MODULES	ADD MAJOR GEO BUILDUP MODULES
②	2 & 1 SEG MODULES/AFT EXP INTEGRAL HAVEN/ADAPTER IVA/UMBIL/MODUL LOGIST ULTRA-LOW COST START	DELIVERY TENDING REVISIT	CENTRAL MODULE AND SPACE PLATFORM	ADD LOGISTICS MODULE	ADD EXPANSION HABITAT	ADD INT & EXT PAYLOAD MODULES	ADD GEO STAGING MODULES
③	2 & 1 SEG MODULES/AFT EXP INTEGRAL HAVEN/ADAPTER IVA/UMBIL/MODUL LOGIST LOW COST START	DELIVERY REVISIT	CENTRAL MODULE AND SPACE PLATFORM	ADD LOGISTICS MODULE	ADD EXPANSION HABITAT	ADD INT & EXT PAYLOAD MODULES	ADD GEO STAGING MODULES
④ *	2 & 1 SEG MODULES/AFT EXP INTEGRAL HAVEN/ADAPTER IVA/UMBIL/MODUL LOGIST MEDIUM COST START	DELIVERY REVISIT		CENTRAL, LOGISTICS & HABITAT MODULES	ADD INT & EXT PAYLOAD MODULES	ADD GEO STAGING MODULES	ADD MAJOR GEO BUILDUP MODULES
SPECIAL ⑤	LATERAL EXPANSION	DELIVERY & REVISIT			ADD INT & EXT PAYLOAD MODULES	ADD GEO STAGING MODULES	ADD MAJOR GEO BUILDUP MODULES
SPECIAL ⑥	EMERG CREW RETURN	DELIVERY	INTRODUCTION TIMING OPTIONAL				
SPECIAL ⑦	EMERG UNMD LOG	DEL/RET	INTRODUCTION TIMING OPTIONAL				

objective and subjective reasoning. Since all of the configurations proposed were based on reasonable and feasible approaches, and since they were being evaluated in relatively gross form, some very basic criteria were applied for a comparison. Moreover, it was deemed important to select two approaches that represented a fair physical difference, so that a broadness-of-view would be inherent in the judgment, as opposed to two similar approaches.

As a consequence of the above, the following criteria were established for the comparative evaluation of the four basic and three accessory option approaches defined in Figure 3.3-1:

- Development Cost/Unit Capability
- Low Cost Escalation Potential
- Flexibility
  - Crew Activities
  - Payload Operations

- Growth Potential
  - Large Payload Buildup
  - Stage and Spacecraft Services
- Safety

These criteria were thus to be applied in the comparison as described in the next section (3.4).

3.4 EVALUATION AND RECOMMENDATION

The results of evaluating the various concepts (in light of the evaluation criteria just defined in Section 3.3) are shown in Figure 3.4-1. In brief, the evaluation narrows the field by (1) disposing of the special feature -- lateral expansion -- because of the potential crowding of elements and related operations; (2) adoption of the four-man, MDAC in-house concept of a low-cost rescue vehicle special feature; (3) adoption of the MDAC in-house concept of a Delta upper stage-based Skylab reboost vehicle for the unmanned logistics vehicle special feature; (4) relegating the Shuttle-tended mode to the low-probability situation wherein only internal payloads such as unmanned/manned life science are available for the first step; and (5) relegating the "low-cost start" also to a special situation case which should probably be inherent as an option in any event, but certainly not an entity which is to be studied as a major system example.

Thus, the considerations described above and the ratings given to each case for the eight key evaluation criteria listed in Figure 3.4-1, combined to result in the selection of Concepts #1 and #4 for detailed systems analysis and definition in the subsequent task.

Figure 3.4-2 illustrates the configurations of Concepts #1 and #4 recommended for further study.

At a level lower than overall configuration conceptualization, various technology utilization options were also considered at this point in the study. Figure 3.4-3 illustrates the matrix of considerations addressed, ranging from existing, through near-term, to maximum advanced technology.

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Figure 3.4-1

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CONCEPT EVALUATION

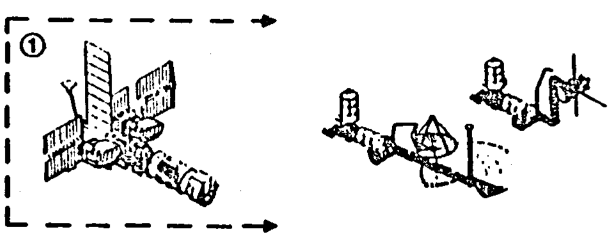
(1-10 RATING; 10 IS BEST) (*SELECTIONS FOR TASK 3)

	EVALUATION CRITERIA / APPROACH	DEV COST UNIT CAPABIL	LOW COST ESCAL-ATION	FLEXIBILITY: CREW ACTIVITIES	FLEXIBILITY: PAYLOAD OPERATIONS	GROWTH POTENTIAL: LARGE PAYLOAD BUILDUP	GROWTH POTENTIAL: STAGE AND SPACECRAFT SERVICES	SAFETY	AVG RATING
① *	3-SEG MODULES/AFT EXP INTEGRAL HAVEN/HABITAT TUNNEL RACK ADAPTER EVA & UMBIL LOGISTICS	6	5	7	3	6	7	7	6
②	2 & 1 SEG MODULES/AFT EXP INTEGRAL HAVEN/ADAPTER IVA & UMBIL LOGISTICS ULTRA-LOW COST START	7	10	8	7	5	6	8	7
③	2 & 1 SEG MODULES/AFT EXP INTEGRAL HAVEN/ADAPTER IVA & UMBIL LOGISTICS LOW COST START	8	9	9	8	9	8	8	8
④ *	2 & 1 SEG MODULES/AFT EXP INTEGRAL HAVEN/ADAPTER IVA & UMBIL LOGISTICS MEDIUM COST START	9	8	9	9	9	9	9	9
⑤ SPECIAL	LATERAL EXPANSION	6	N/A	6	7	5	6	6	6
⑥ SPECIAL	EMERGENCY CREW RETURN	9	N/A	10	N/A	N/A	N/A	10	9
⑦ SPECIAL	EMERG UNMD LOG	8	N/A	10	N/A	N/A	N/A	10	9

Figure 3.4-2

VFR073

APPROACHES RECOMMENDED FOR DETAILED SYSTEM ANALYSIS (TASK 3)



- 3 Segment Modules
- Aft Expansion
- Integral/Haven/Habitat
- Tunnel Rack Adapter
- EVA/Umbil/Modular Logistics

- 2 + 1 Segment Modules
- Aft Expansion
- Integral Haven/Adapter
- IVA Umbil/Modular Logistics
- Medium Cost Start

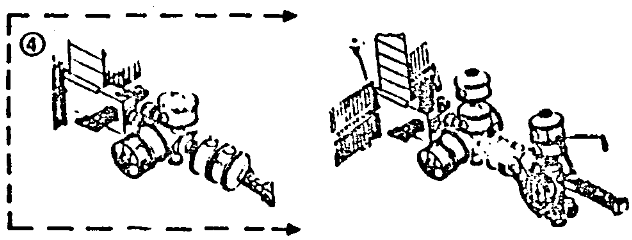


Figure 3.4-3

VFR080

TECHNOLOGY UTILIZATION OPTIONS*

	TECHNOLOGY USED		
	MAXIMUM EXISTING	EXISTING/ NEAR-TERM	MAXIMUM ADVANCED
EXISTING TECHNOLOGY			
• CONFIGURATION/STRUCTURES			
– SPACELAB (2 SEG) HABITAT/PAYLOAD MODULE	X		
– SPACELAB (1 SEG) DEDIC PAYLOAD MODULE	X	X	
– SHUTTLE AIRLOCK/HATCH	X	X	X
• SUBSYSTEMS			
– SPACELAB ECLSS, POWER & DATA MGT (MOD)	X	SOME	
– SHUTTLE ECLSS COMMUNICATIONS/DATA CREW SYSTEMS	X X X	X X X	SOME X
NEAR-TERM TECHNOLOGY			
• SUBSYSTEMS			
– SPACE PLATFORM			
· POWER DISTRIBUTION		X	
· THERMAL CONTROL DISTRIBUTION		X	
· COMMAND/DATA MGT		SOME	
ADVANCED TECHNOLOGY			
• CONFIGURATION/STRUCTURES			
– CENTRAL CREW/DOCK MODULE	X	X	X
– HABITAT/PAYLOAD MODULE		X	X
–PAYLOAD MODULE			X
–THERMAL/RADIATION SHIELD	X	X	X
–DOCK/BERTH MECHANISM	X	X	X
• SUBSYSTEMS			
– ENVIRONMENTAL CONTROL/LIFE SUPPORT		X	X
–POWER DISTRIBUTION			X
–COMMAND/DATA MANAGEMENT	(SOME)	(SOME)	X

*ASSUMES USE OF SPACE PLATFORM VEHICLE

Note that in any approach such items as the Shuttle airlock and hatches, ECLSS and communications/data components would probably be used. The only near-term technology choices would be from the forthcoming Space Platform development.

In the Advanced Technology, all optional approaches require an all new central module, thermal radiation shields and docking/berthing mechanisms, the latter being needed in considerable quantity regardless of approach.

In the communications/data area, there is also the high probability that the explosive nature of developments would force the logic of using whatever the latest technology is in the mid-80s in favor of the 1970s technology of the Spacelab or even Shuttle.

In summarizing this section, therefore, the objectives of creating and shaping various concepts have been achieved, as has the narrowing of candidates for selection of two for the next task in the study.

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Section 4
SYSTEMS ANALYSIS AND DEFINITION (SUBTASK B.3)

The major activity in this subtask was to study in detail the two system approaches selected in the prior subtask (B.2), namely approaches #1 and #4. Such information was to be used to support a comparison of the two in the next subtask (B.4) for the selection of one for recommendation.

Subsection 4.1 outlines the approach to the in-depth analysis, namely the concept-formulation of each of the modules of the configuration followed by system-integral considerations such as operations, maintenance and safety and finishing with a detailed treatment of each subsystem and the interfaces inherent therein. Subsection 4.2 develops approaches #1 and #4 in greater detail and various configurations and sizing tradeoffs. Subsection 4.3 deals with Ground and Flight Operations. Subsection 4.4 addresses Maintenance, Reliability and Safety, and 4.5 covers the analysis of the subsystems. Finally, Subsection 4.6 defines the interfaces from a subsystem perspective.

Figures 4-1 and 4-2 illustrate the task relationship within the study and subtask flow, respectively.

4.1 IN-DEPTH ANALYSIS (MODULAR PLAN)

The format for this analysis is based on the fact that both approaches (#1 and #4) are made up of five basic elements, namely:

- Space Platform (12.5 and 25 kW)
- Central Adapter Module
- Habitat Module
- Logistics Module
- Exterior Payload Module

Since the Space Platform was specified in the study and since the interior payloads are viewed primarily as equipment installed in a habitat, the study focused primarily on modules for Central/Adaption, Habitation, Logistics and Exterior Payload operations.

Figure 4-1

TASK B — MANNED PLATFORM CONCEPT

VFK494-2

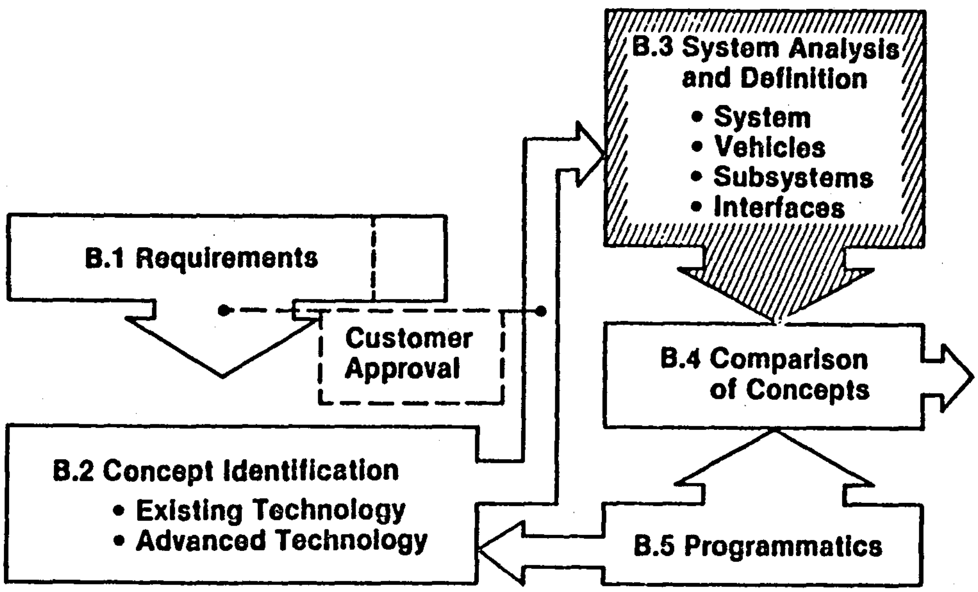
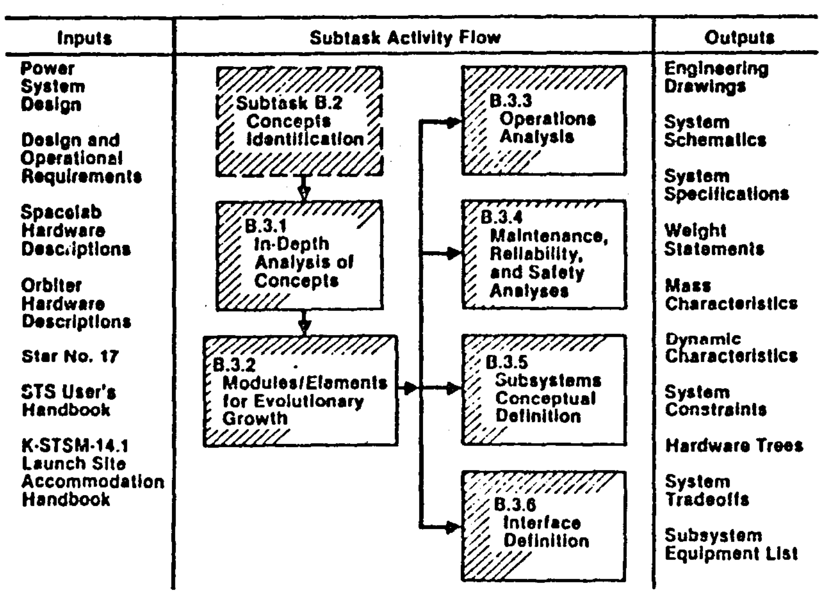


Figure 4-2

SYSTEMS ANALYSIS AND DEFINITION (SUBTASK B.3)

VFK498N



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4.2 MODULES/ELEMENTS FOR EVOLUTIONARY GROWTH

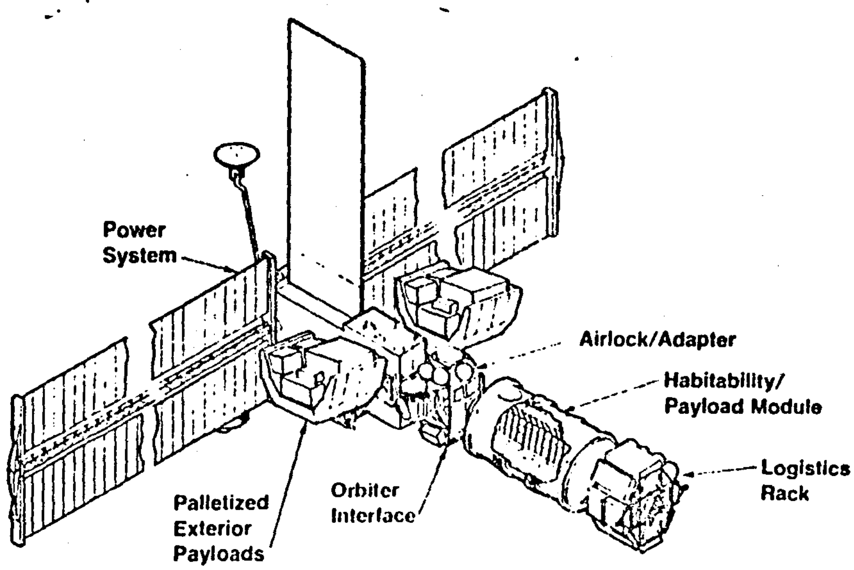
This subsection is arranged to first of all give overviews of the basic characteristics of the two approaches (#1 and #4) and then to address the central adapter, habitat (including crew sizing impact) and logistics module concepts in detail.

4.2.1 Overview of Approach #1

This approach begins with the configuration shown in Figure 4.2.1-1 and incorporates the Space Platform as a utility resource. A minimum-capability adapter was used and incorporated a tunnel, an airlock for EVA and a small select amount of external stores. The adapter's main passageway function was to provide the pressurized access from Orbiter to Platform. However, two payload ports were included for growth consideration. The habitat was a three-segment Spacelab with accommodations for up to four crewmen. The three-segment was considered in order that a substantial amount of mission payload equipment could be incorporated. The initial logistics system was an unpressurized rack

Figure 4.2.1-1

BASIC MANNED PLATFORM
(APPROACH #1)



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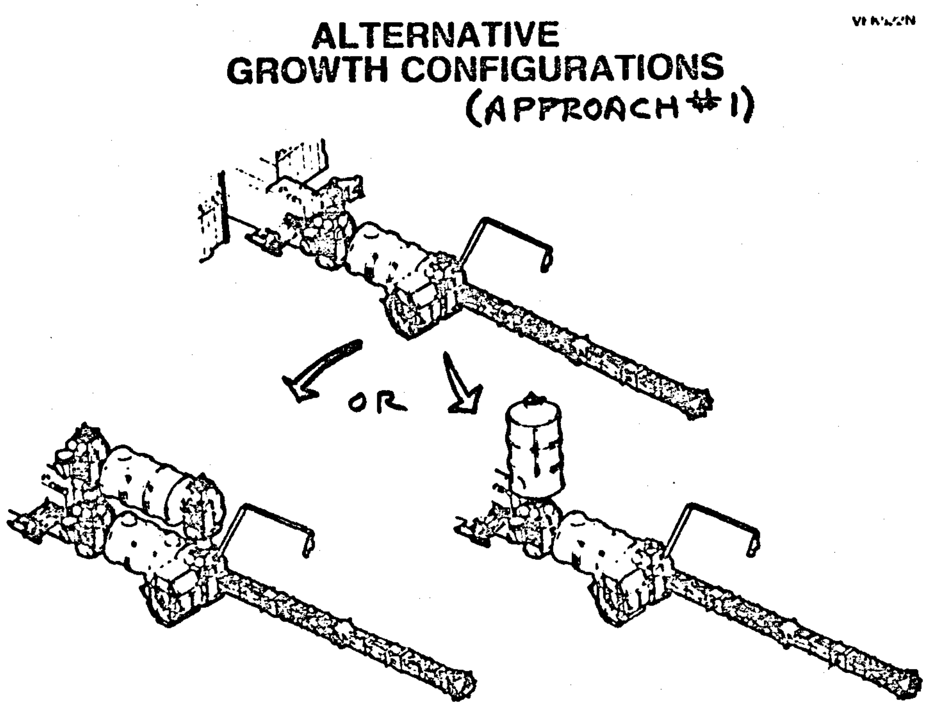
configured to fit within the Orbiter cargo bay and contain high pressure consumables, potable H_2O and spares. Food and other crew-related items or specimens requiring a controlled environment would be delivered in the Orbiter mid-deck area. Access to the logistics rack was via EVA. Two palletized payloads are berthed to the First Order Space Platform ± axis payload arms.

Growth capabilities are primary factors in concept formulation. Growth alternatives for Approach (1) is shown in Figure 4.2.1-2 and is accomplished by the addition of one or more of the basic Platform elements. Addition of a second adapter offered the opportunity of adding a payload support beam and manipulator. A considerable growth step can be accomplished with the addition of one three-segment module berthed to the initial adapter. However, addition of other

Figure 4.2.1-2



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types of units as shown on Figure 4.2.1-3 provides many options for growth, in this case lateral. The philosophy here is to add modules in standard steps of considerable volume each, as opposed to smaller volumes, i.e., one-segment or two-segment modules, or some of each. Configuration of the payload beam is predicated on the mission elements required to satisfy the mission objective. Figure 4.2.1-4 identifies some of those elements such as a large, space-assembled payload and the OTV required to place it on-orbit. Space assembly suggests berthing requirements for palletized components within easy reach of the manipulator system. As a result, the initial beam configuration incorporated folding and rotating elements is also shown in Figure 4.2.1-4, enabling it to service OTVs, satellites, large and small diameter antennas. A cursory evaluation of an alternate lateral expansion arrangement shown in Figure 4.2.1-5 was made to determine if space assembly of large reflectors could be accomplished with the initial platform elements. Mounting the beam on the adapter +Y axis appeared feasible; however, the concept appeared impractical from a control standpoint and solar array shadowing. Figure 4.2.1-6 illustrates the

Figure 4.2.1-3

GROWTH OPTION (LATERAL)

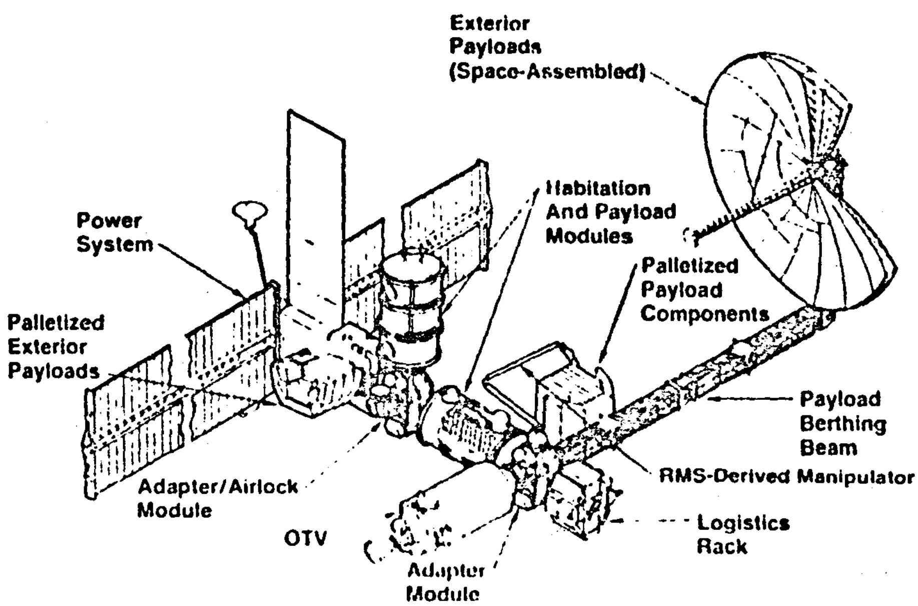

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Figure 4.2.1-4

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ALTERNATIVE CONFIGURATIONS
BERTHING BEAM

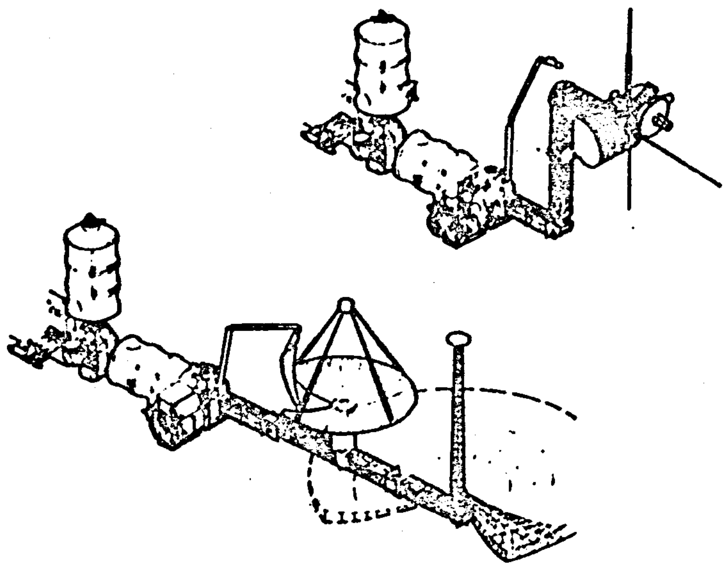

Figure 4.2.1-5

LATERAL BERTHING BEAM
INSTALLATION

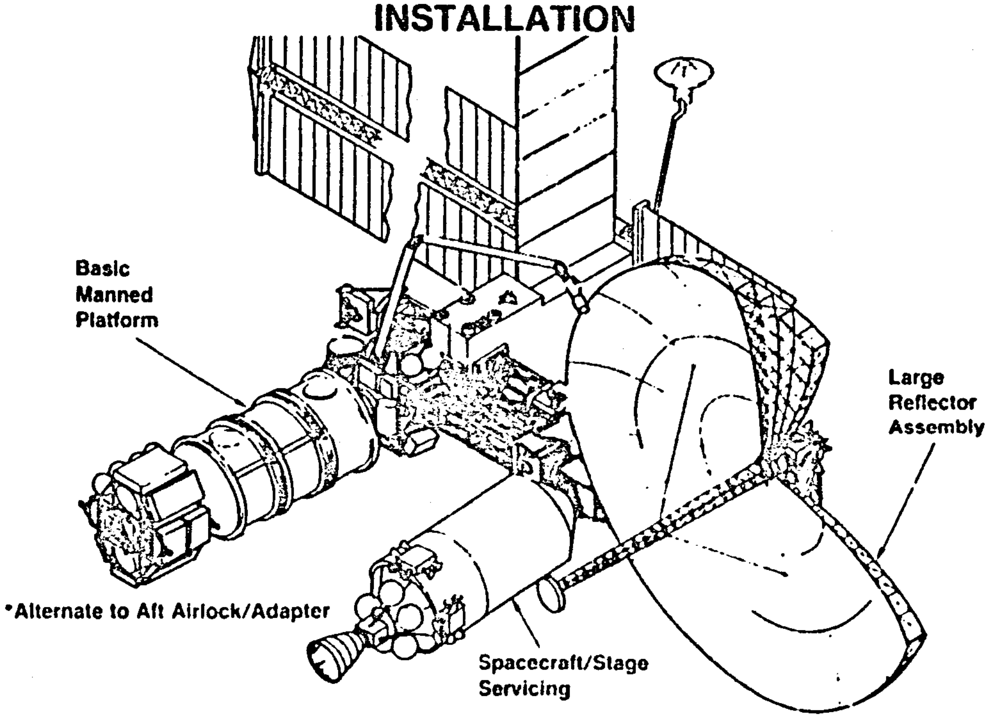

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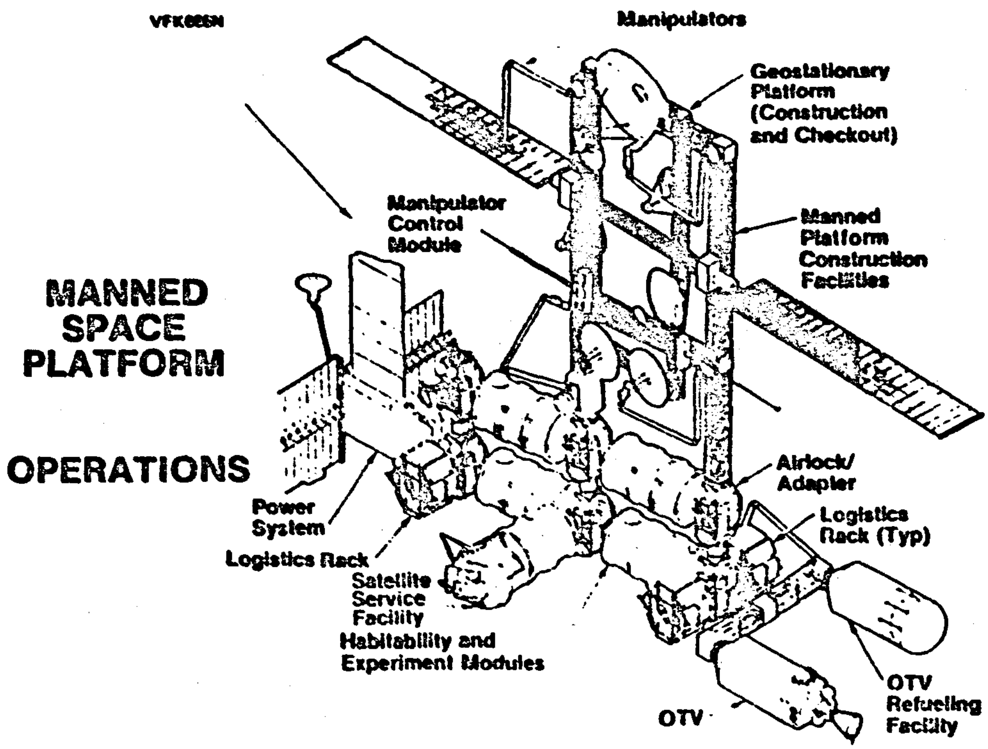
Figure 4.2.1-6



possibility of growth to a complex Space Center with multiples of the basic three modules, shown here for the assembly of a geosynchronous platform and later service as an OTV staging base for periodic visits to such a platform.

4.2.2 Overview of Approach #4

The basic Approach #4 Platform shown in Figure 4.2.2-1 is sized for 90-day on-orbit life with a 30-day contingency and assumes that the Power System and the Electrophoresis Unit were launched together. The adapter and habitat are sized for launch as one payload. As a result, with two Orbiter launches, the Platform is fully manned conducting pharmaceutical experiments. Extended duration beyond 90 days is accomplished with addition of a gas/liquid resupply pack as shown in Figure 4.2.2-2. Also launched with the resupply pack would be a Life Science Research Lab and a Life Science Specimen Holding Facility each berthed to the Platform as shown. In addition to the atmospheric supplies, other crew-related expendables would be delivered in the Orbiter mid-deck area. The

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Figure 4.2.2-1

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BASIC MANNED PLATFORM

(APPROACH #4)

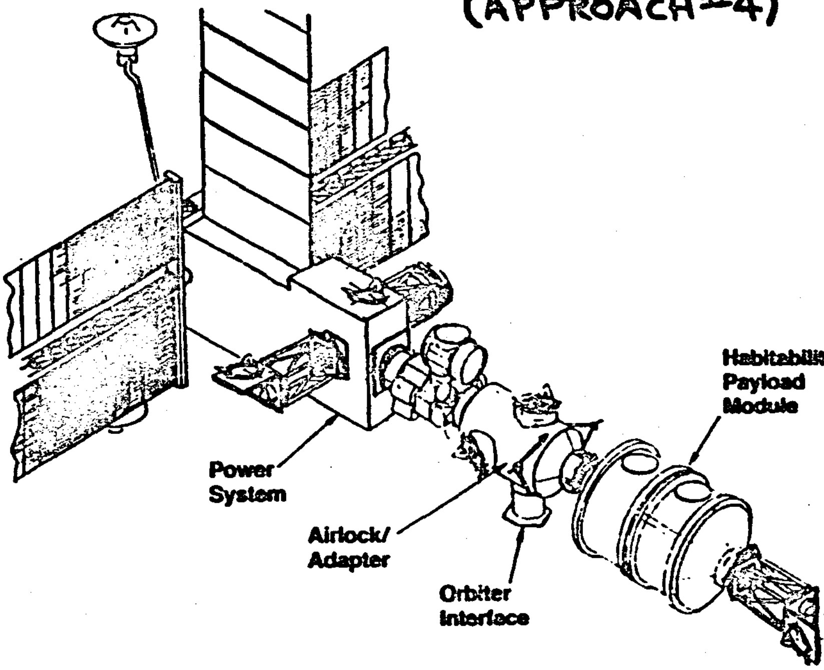
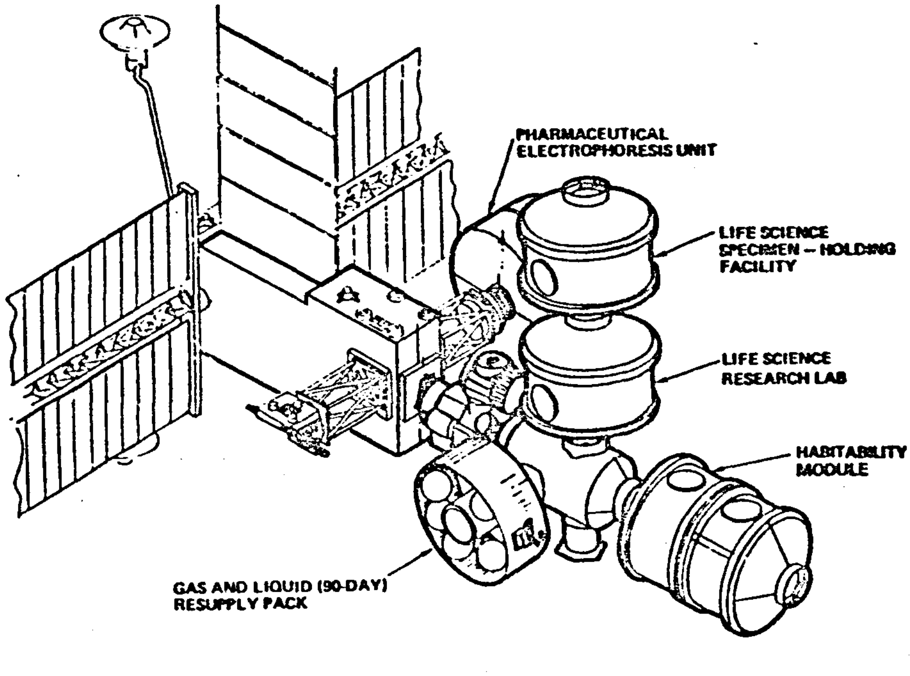


Figure 4.2.2-2

MANNED PLATFORM WITH PAYLOAD MODULES (APPROACH #4)



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position of the Holding Facility was selected due to its functional relationship to the Research Lab and the frequency of replacement. Figure 4.2.2-3 shows the addition of a crew rescue vehicle. Growth of the linear configuration is accomplished with the addition of a modified Adapter Module, manipulator and payload assembly beam, as shown in Figure 4.2.2-4, integrated as a single unit and launched together. The Platform has thus the added capability for spacecraft servicing and retrievability, payload assembly, OTV testing and large experiment accommodations, as shown in Figure 4.2.2-5.

Figure 4.2.2-3
MANNED PLATFORM WITH RESCUE VEHICLE

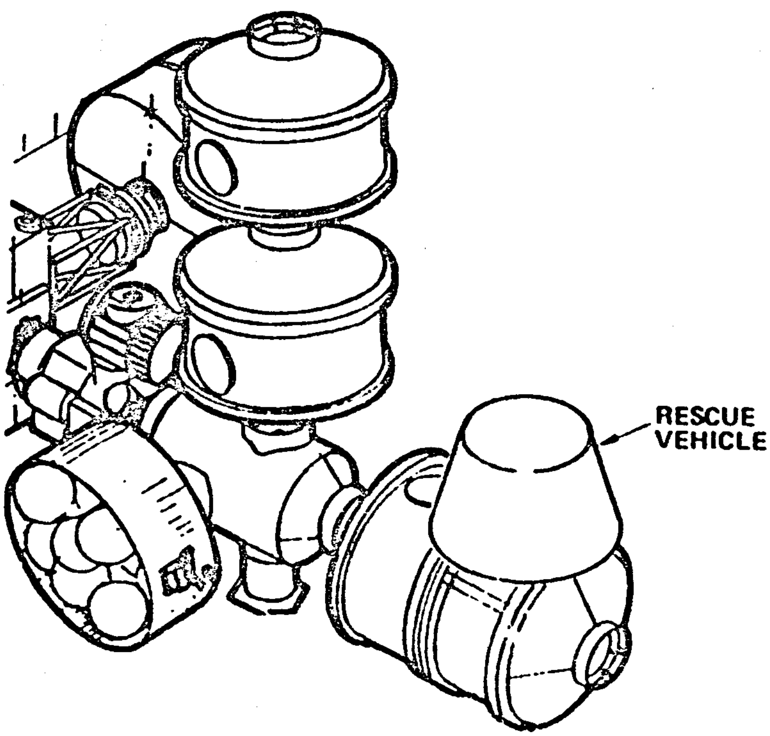

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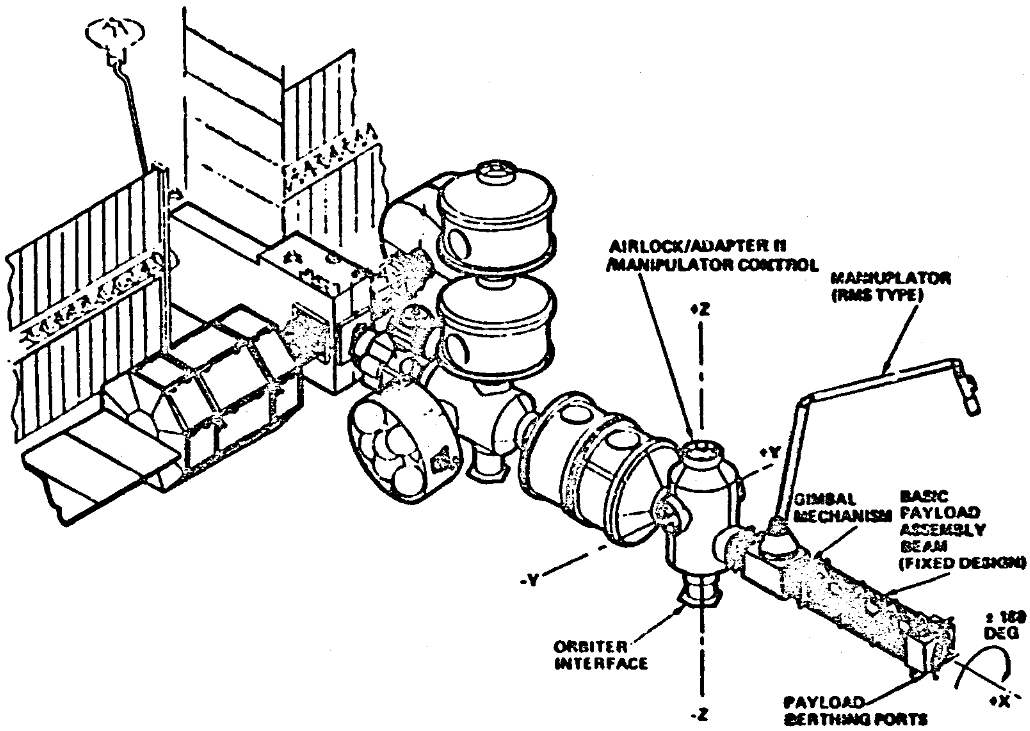
Figure 4.2.2-4

MANNED PLATFORM GROWTH STEP NO.1



4.2.2.1 Approach (1) With 180-Day Logistics

The concept shown in Figure 4.2.2.1-1 is the basic linear platform configured for a crew of three performing Life Science Experiments. Study results have indicated a large percentage of crew-related expendables as well as experiment specimens requiring a controlled environment during all phases of the mission. Also, volume requirements indicate a need for a separate pressurized resupply module. The concept shown combines the gas and liquid resupply pack with a one-segment Spacelab. Use of the Spacelab segment provides enough volume to allow 180 days of expendables to be stored and used from or transferred to platforms at crew discretion. With addition of payloads shown in Figure 4.2.2.1-2, the platform is fully operational.

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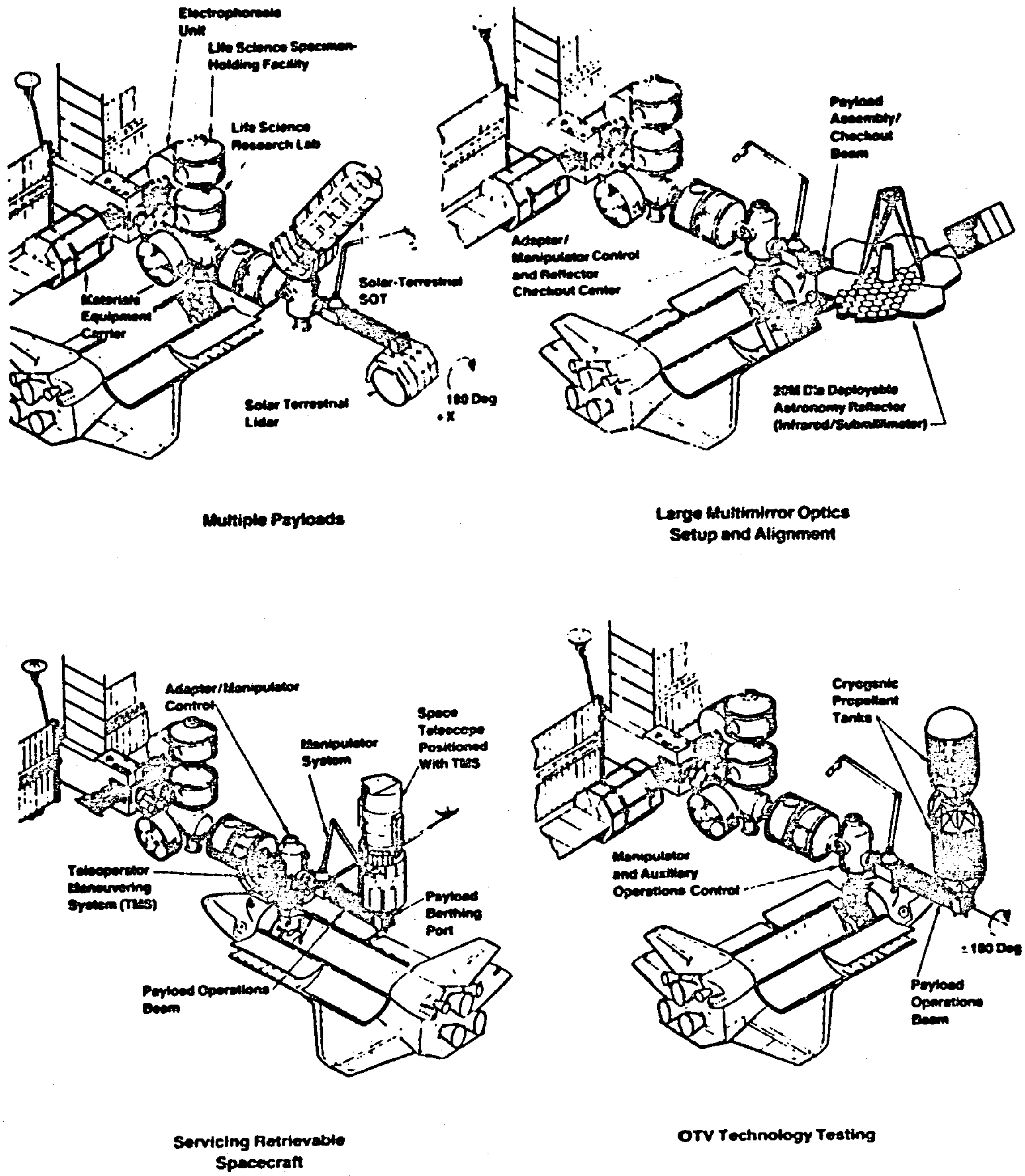

Figure 4.2.2-5. MANNED PLATFORM OPERATIONAL GROWTH OPTIONS

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Figure 4.2.2.1-1

MANNED PLATFORM — 180 DAY LOGISTICS

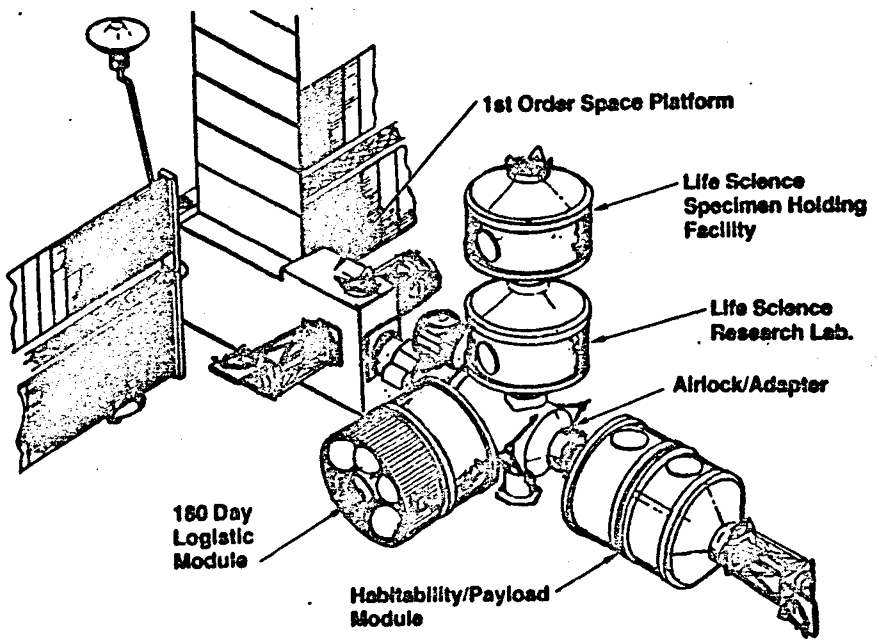
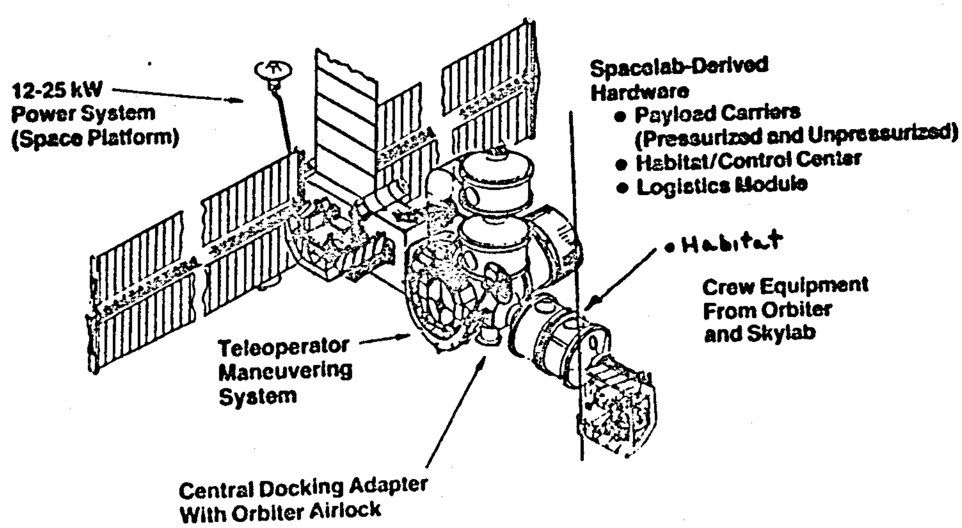


Figure 4.2.2.1-2

EARLY MANNED PLATFORM



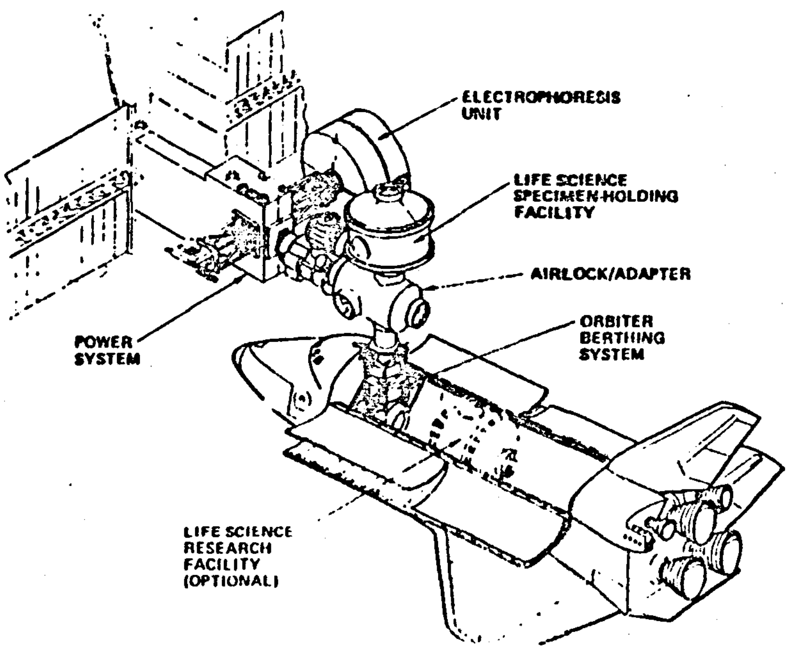
4.2.2.2 Initial Shuttle-Tended Option

This concept can be operated initially on-orbit in a Shuttle-tended or sortie-like mode. Berthing of the airlock-adapter module to the Power System, shown in Figure 4.2.2.2-1, provides the capability of performing selected experiments in a shirtsleeve environment.

The configuration shown incorporates a Life Science Research Facility which could be launched in the cargo bay as a non-deployable payload and used on-orbit for research during the short orbit stay time, then returned to earth for further study. The specimens would remain on-orbit until revisited by the Orbiter. With this configuration, man can be added on a permanent basis as the program or mission requirements dictate. Detailed efforts on this option were not pursued further in the study (after midterm) by agreement with MSFC because of the higher interest in the autonomous, long-term manned mode.

Figure 4.2.2.2-1

SHUTTLE-TENDED CONFIGURATION VFM277N



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4.2.3 Concept Development of Modules

Since sizing and configuration of the various modules depended on the allocation of functions to be performed by each element, each element was assigned subsystem functions to be incorporated within that element, as shown on Figure 4.2.3-1 and related interfaces on Figure 4.2.3-2. From this list, subsystem interfaces, between elements, were identified and subsystem schematics identified hardware components that would be required in each module. The next task was to define the physical characteristics of each module or element each within delivery, assembly and operations parameters. Figure 4.2.3-3 summarizes and Figure 4.2.3-4 depicts the variety of options studied.

Figure 4.2.3-1

ALLOCATION OF SUBSYSTEM FUNCTIONS

POWER SYSTEM

- STRUCTURE/MECHANICAL
  - PAYLOAD INTERFACE STRUCTURE(S)
  - PAYLOAD INTERFACE MECHANISM(S) (ACTIVE) (3 PLACES)
  - ORBITER BERTHING MECHANISM (UNMANNED SORTIE MODE)
- ELECTRICAL POWER SYS (EPS)
  - POWER SOURCE
  - BATTERIES, CHARGERS, AND REGULATION
  - POWER DISTRIBUTION AND CONTROL
- THERMAL CONTROL SYS (TCS)
  - HEAT REJECTION RADIATOR
  - INTERFACE HEAT EXCHANGERS AND DISCONNECTS
  - TEMPERATURE CONTROLS
  - F-21 LOOP

AIRLOCK/ADAPTER

- STRUCTURE/MECHANICAL
  - ORBITER BERTHING/DOCKING INTERFACE (PASSIVE)
  - POWER SYSTEM/BERTHING INTERFACE (PASSIVE)
  - PRESSURIZED VOLUME FOR SECONDARY SHELTER
  - PAYLOAD BERTHING PORTS (ACTIVE)
  - SECONDARY SUPPORT STRUCTURE
  - PRESSURIZED VOLUME FOR EVA (AIRLOCK)
  - EMERGENCY VENT SYSTEM
  - RESTRAINTS AND LOCOMOTIVE AIDS
- ELECTRICAL POWER SYSTEM
  - POWER SYSTEM STATUS AND MONITORING
  - POWER DISTRIBUTION AND CONTROL
  - INVERTERS*
  - LIGHTING
  - EMERGENCY POWER DISTRIBUTER
- THERMAL/ENVIRONMENTAL CONTROL & LIFE SUPPORT SYS
  - REPRESSURIZATION TANKS
  - ATMOSPHERE REVITALIZATION
  - ATMOSPHERE CONTROL
  - AVIONICS COOLING LOOP
  - WATER LOOP AND PUMP PKGS
  - EVA SUPPORT

HABITABILITY/PAYLOAD MODULE

- STRUCTURE/MECHANICAL
  - INTERFACE MECHANISM – 1 ACTIVE AND 1 PASSIVE
  - PRIMARY PRESSURE SHELL
  - METEROID SHIELDING AND THERMAL BLANKET
  - INTERNAL SECONDARY SUPPORTS
    - RACKS & OVERHEAD STRUCTURE
    - FLOOR
  - OPTIC WINDOW & VIEW-PORT(S)
- ELECTRICAL POWER SYSTEM
  - POWER DISTRIBUTION AND
  - CONTROL
  - EMERGENCY POWER DISTRIBUTION (BATTERIES)*
  - LIGHTING
  - INVERTERS
- THERMAL ENVIRONMENTAL CONTROL & LIFE SUPPORT SYS
  - ATMOSPHERE CONTROL
  - ATMOSPHERE REVITALIZATION
  - AVIONICS COOLING LOOP
  - WATER DISTRIBUTION
  - WATER LOOP

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Figure 4.2.3-1 (Cont.)

ALLOCATION OF SUBSYSTEM FUNCTIONS (CONT)

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POWER SYSTEM

- COMM & DATA MGMT SYS
  - GROUND COMMUNICATION
  - ORBITER COMMUNICATION
  - DETACHED MODULE/EVA COMM
  - PS DATA ACQUISITION
  - PS COMMAND PROCESSING
  - PS PAYLOAD SUPPORT
- REBOOST/DEBOOST SYS
- ATTITUDE CONTROL SYS (ACS)
  - CMG INSTL
  - HORIZON & SUN SENSORS
  - RATE GYROS, ETC
  - MAGNETIC TORQUERS

AIRLOCK/ADAPTER

- COMM & DATA MGMT SYS
  - ENGINEERING DATA ACQUISITION
  - DATA PROCESSING
  - DATA STORAGE
  - DATA MULTIPLEXING
  - DATA DISPLAY/KEYBOARD
  - C&W PANEL
  - TV CAMERA/MONITOR
  - VOICE INTERCOMM
- HABITABILITY
  - WASTE MANAGEMENT
  - FOOD FREEZERS
  - TOOLS
  - RESTRAINTS AND LOCOMOTION AIDS
  - EVA SUITS STORAGE AND REPAIR EQUIP
  - EMERGENCY FOOD STORAGE

HABITABILITY/PAYLOAD MODULE

- COMM & DATA MGMT SYS
  - ENGINEERING DATA ACQUISITION
  - BACKUP DATA PROCESSING
  - DATA DISPLAY/KEYBOARD
  - C&W PANEL
  - TV CAMERA/MONITOR
  - VOICE INTERCOMM
  - SCIENCE DATA ACQUISITION
- HABITABILITY
  - FOOD FREEZER AND REFRIGERATOR
  - EXERCISE AND RECREATION
  - HYGIENE
  - MEDICAL TREATMENT
  - CREW QUARTERS
  - RESTRAINTS AND LOCOMOTION AIDS
  - TOOLS
  - FOOD PREPARATION AND EATING
  - EMERGENCY WASTE
  - PERSONAL RESCUE SYSTEM

Figure 4.2.3-2

VFM332N

BASIC CONFIGURATION INTERFACES

Interface → / Utility ↓	Airlock Adapter-Payload Module	Airlock Adapter-Power System	Airlock Adapter-Orbiter	Airlock Adapter-Habitability Module	Airlock Adapter-Airlock	Habitability Module - Aft Port	Airlock Adapter-Logistics Module
Power, Main Bus	0	0	0	0	0	0	0
Communications	0	0	0	0	0	0	0
Data Management	0	0	0	0	0	0	0
Thermal Fluid	0	0		0	0	0	
Atmosphere (N_2 and O_2)				0	0	0	0
Control Circuits	0	0	0	0	0	0	0
Potable H_2O	0			0		0	0
Pump Down System					0		
Man Access (IVA)	0		0	0	0	0	0
Atmosphere Interchange (RCS)	0						0

Figure 4.2.3-3

VFO801

CONFIGURATION ELEMENT OPTIONS

Basic (And Growth) Central Modules

- A Through I Options

Habitat Module

- 2-and 3-Segment Spacelabs

Payload Module

- 1-and 2-Segment Spacelabs

Logistics Modules

- Unmanned
- Unmanned + Manned
- Unmanned/Manned
- 90 Days
- 180 Days

Exterior Operations Module

- Short
- Long
- Long With Aux RMS

Figure 4.2.3-4

VFR071

CONFIGURATION ELEMENT OPTIONS

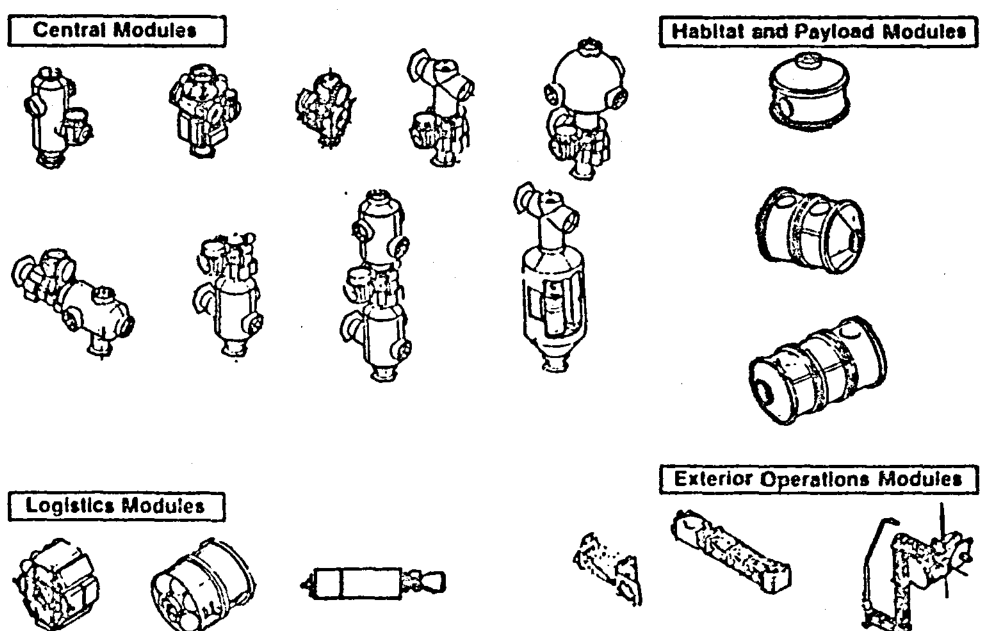

Table 4.2.3-1 lists the numerous activities included in the overall concept formulation for the system elements. Table 4.2.3-2 lists the operational sequence options for growth porting.

4.2.3.1 Central Adapter (Airlock) Module

During the initial concept formulation of the study, interface parameters between the Power System, Orbiter and MSP were established. On-orbit clearances required by the Orbiter and RMS to prevent contact were established and each concept was measured against these various requirements. Figure 4.2.3.1-1 shows the clearance requirements at the SP Orbiter interface.

Final configuration of adapters will depend largely on the final design of the Space Platform (SP) and the SP/Orbiter berthing mechanism. Their design establishes the distance from the Orbiter interface at Xo 619.0 to the SP interface in both the (+Z) and (-X) direction.

The 35.0-inch clearances are established by the Orbiter to prevent contact between it and RMS attached payloads. The RMS is required to stop within a 2.0-foot distance. Therefore, a configuration selected must be outside the clearance line shown.

To place a full diameter on the (-Y) port, the centerline must be a minimum of 1.8 m (70.0) from Sta. Xo 619. This permits the RMS to maneuver into position and rotate 180° for attachment to payload on the (-Y) port.

Nine adapter configurations, shown in Figure 4.2.3.1-2, were evaluated. The concepts range from a minimum configuration, providing only shirtsleeve transfer and airlock functions, to a complete "workshop" that would provide many services to the complete MSP. Each concept was evaluated based on requirements from early Task B, allocation of functions, interface parameters, logistics requirements and Orbiter/SP configuration parameters. Two concepts, a Z-axis configuration and an X-axis concept, shown in Figure 4.2.3.1-3, emerged as candidates for further study. Both concepts, shown in Figure 4.2.3.1-4, are attempts to configure integrated airlock/adapters with minimum distances between interfaces and maximum diameter within cargo bay limitations.

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Table 4.2.3-1

MSP CONCEPT FORMULATION

Orbiter Physical Interface Parameters Established

- **Keel Fittings and Longeron Fittings Availability**
- **RMS Envelope Restrictions**
- **Orbiter Cabin Clearances**
- **Orbiter Berthing Envelope**

MSP/Orbiter and Intrasystem Interface Requirements Established and Evaluated

- **PS to MSP**
- **MSP to MSP Elements**
- **MSP to Orbiter**
- **PS to Orbiter**

Subsystem Functions Allocated to Major Elements of MSP

- **PS, Airlock/Adapter, Habitability Module**

Optional Approaches To Initial Capability

- **Primary Unmanned (Manned During Shuttle Visit)**
  - **Provides Increased Internal Experiment Cability**
  - **Enables Life Science, Etc., Specimens and Equipment to Be Evaluated On Ground Minimizing On-Orbit Logistics**
  - **Life-Science-Type Lab Occupies Large Portion of Cargo Bay Wt and Vol On Each Flight-Limits Payload Logistics**
  - **Enables Design of Maximum Sized Airlock/Adapter For Future Growth Considerations**
  - **Does Not Require Pressurized Logics System Until Later In Program**

- **Sustained Manned Residence From Outset**
  - **After Second Launch – Cargo Wt and Vol Allocated 100% To Payload (Except For Logistics Flights)**
  - **Internal Experimentation Limited During Early Phase Of Program**
  - **Design Characteristics Of Airlock/Adapter Module Influenced By Cargo Bay Space Allocation**

Table 4.2.3-1 (Cont.)

MSP CONCEPT FORMULATION (CONT)

Nine Candidate Airlock/Adapter Options Investigated

Two Airlock/Adapter Configurations Selected For Further Study. Concepts Measured Against Identified Requirements and Parameters

- Z-Axis-Oriented Concept
- X-Axis-Oriented Concept

X-Axis A/A Concept Selected For Detail Configuration Analysis

- Maximum External Size and Shape Determined Within Established Orbiter Physical Parameters and Launch Envelope
- Internal Arrangements Investigated to Maximize Use of Available Volume
- "1-g" Orientation Selected With Four Radial Berthing Ports and Two End Ports

Two Candidate Habitability/Payload Modules Evaluated

- A 2-Segment Spacelab
- A 3-Segment Spacelab

A 2-Segment Spacelab Was Selected For Detail Configuration Analysis

- Internal Arrangements Investigated to Maximize Use of Available Volume
  - Four Crew Sleep Accommodations Concepts Evaluated
  - 1-g and 0-g Orientations Investigated
  - Internal Volume Allocation Options Investigated
  - Crew Size and Subsystem Volume Requirements Established

  1-g Orientation With Private Quarters For Three Crewmen Was Selected For Continued Subsystem Analysis. This Selection Is Considered Minimum Impact on Current Spacelab Systems and Makes Maximum Use of Current Spacelab Equipment.

Detailed Equipment List Prepared: Habitat, Airlock/Adapter, Logistics Module

Five Logistics Options Evaluated

- All EVA Transfer
- IVA Solids, EVA Gases
- IVA Solids, Press Transfer Gases
- IVA Solids From Middeck, Tank Module on MSP
- Tank Module For Gases, Pressurized Module For Solids

- An Integrated Pressurized Module With External Mounted Gas Tanks Selected For Additional Configuration and Operational Analysis

Table 4.2.3-1 (Cont.)

MSP CONCEPT FORMULATION (CONT)

Three-Man Basic Sustenance Weight and Volume Requirements Established For a 90-Day and a 180-Day Resupply Cycle

Favored Logistics System Is As Follows

- **1-Segment Spacelab Module With**
  - **Interior Water Resupply Tanks**
  - **Exterior Atmospheric Resupply Tanks**
- **System Sized For 180-Day Resupply Cycle**
- **Crew Rotated At 90-Day Intervals With Crew Equipment Transported In Middeck**
- **Interior Stowage Volume for Exchange of Total Payload In Habitability Module**

Table 4.2.3-2

OPERATIONAL CONSIDERATIONS IN CONFIGURATION DEVELOPMENT

- **Activation (Assembly of):**
  - Power System + Adapter-Access Module
  - Power System + Adapter-Access Module + Manned Module I

    Tended Free Flyer Only
  - Power System + Adapter-Access Module + Manned Module I + Logistics Module
- **Capability Expansion (Add):**
  - Manned Module II, III
  - Dual Adapter-Access Module
  - Experiment Module(s)
  - Exterior Payload Support Beam
- **Payload Addition/Removal/Support**

  Interior Payloads

  Exterior Payloads
  - On Adapter Access Module
  - On Exterior Payload Support Beam
- **Platform Resupply (Exchange)**

  Logistics Module

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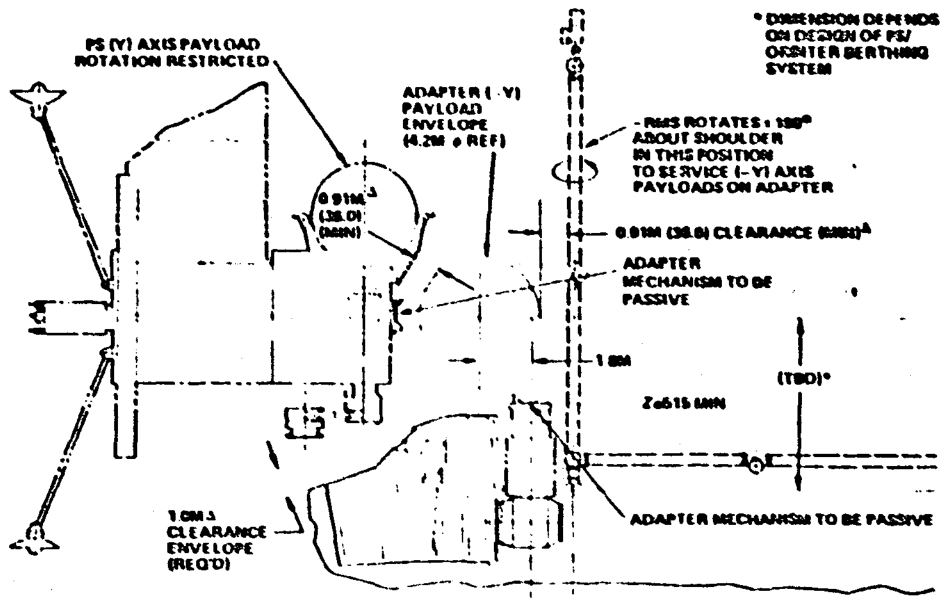
Figure 4.2.3.1-1

AIRLOCK/ADAPTER CONFIGURATION PARAMETERS



▲ THIS CLEARANCE REQUIRED TO BE COMPATIBLE WITH RMS 2.0 FT STOPPING DISTANCE REQUIREMENT

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Figure 4.2.3.1-2

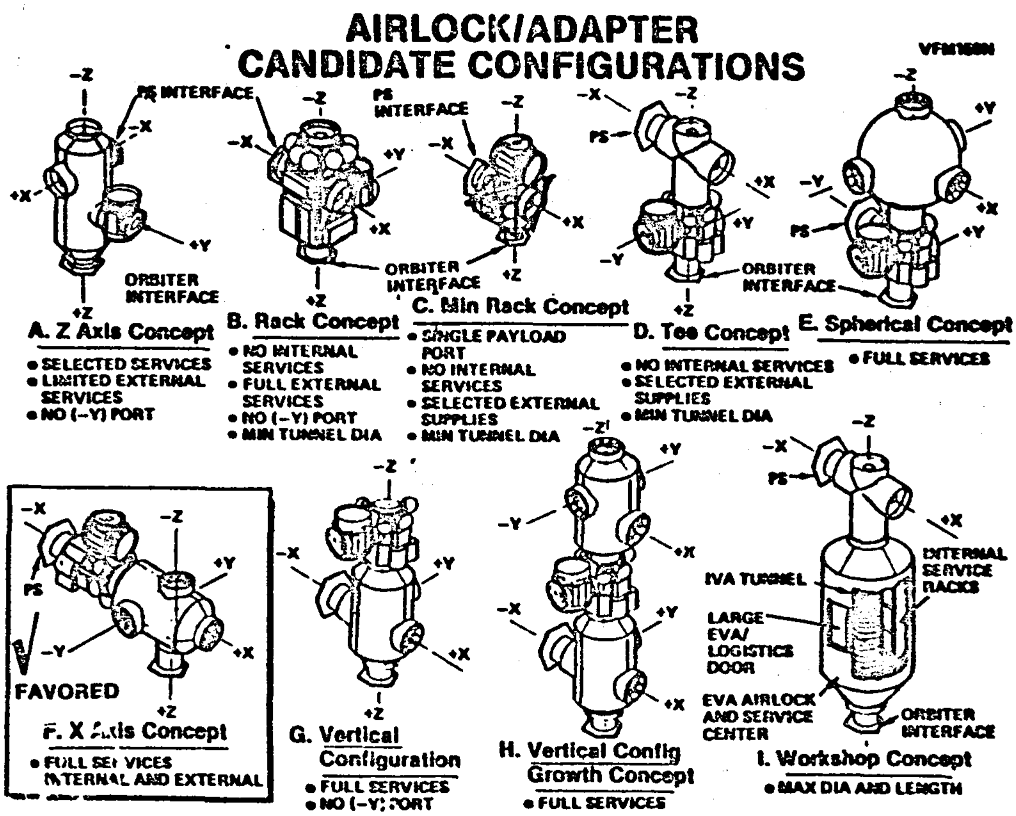

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Figure 4.2.3.1-3

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AIRLOCK/ADAPTER CONCEPT FORMULATION

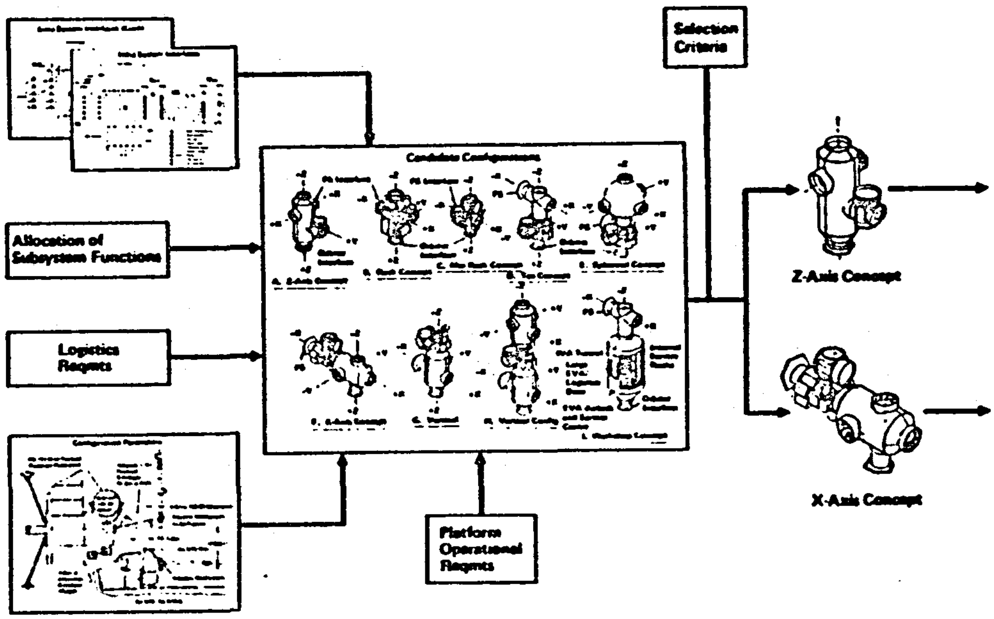

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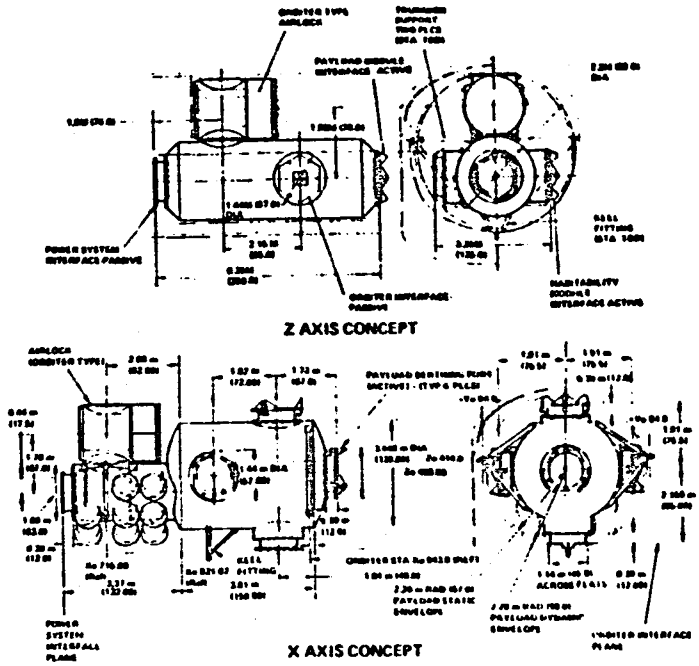
Figure 4.2.3.1-4

AIRLOCK/ADAPTERS – LAUNCH CONFIGURATIONS



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It is important here to define why <u>the rack-type adapter inherent in Approach (1) was dropped</u> at this point in the study.

The central module of the manned Space Platform is envisioned as the most important element of the configuration. It should be capable of supporting a basic crew, say two, so that some minimal payload activity can be sustained from the very outset of the buildup. With this concept then, utilization of that module can be expanded to include that of a basic safe haven or retreat in case of emergency. With the volumes associated with the foregoing features, it can readily be used as a multi-path passageway in between as many as three plug-in modules and the Oribter.

Also, since it is our conviction that the waste management subsystem should not be in the habitat (based on Skylab complaints) and since a safe haven needs such a subsystem, it again needs some convenient installation volume outside of the habitat and early in the buildup--so, where better than in the central adapter module. Also, water storage must be provided inside of a safe haven pressure volume and not too far from the logistics vehicle port (since the tanks are ECA transferred and installed on Shuttle revisits),again where better than the central module.

Also, for many reasons a mini-control center and airlock is best incorporated in the "most" central module.

Therefore, at this point in the study it is concluded that the rack-type central adapter concept could not fulfill many of our system requirements and it was thus dropped from further study. Approach (1), therefore, hereafter was assumed to have the same type central adapter as Approach (4).

The lengths are established by observing the clearance requirements between SP and Orbiter. This dimension will vary according to SP design and launch packaging parameters.

Location of payload in the Orbiter cargo bay is limited between Stations Xo 663.00 and Xo 1302. The Space Shuttle System Payload Accommodation document, JSC 07700, defines the space allocation reserved for the Orbiter berthing

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system as being from Xo 582 to Xo 660.0. A three-inch clearance is provided between the berthing system and the MSP elements. Available cargo bay volume for the adapter is further restricted by installation of the habitability module in an attempt to launch both modules in one flight.

The JSC 07700 document also defines the location of active longeron and keel fittings that can be used by payloads to be removed from the cargo bay. The first available active keel fitting for the habitat module is at Station Xo T124.07. Moving aft, the next available fitting is Station Xo 1159.47. This location placed the module outside the cargo bay envelope. Once the habitat module location was established, sequential development of the adapter, shown in Figure 4.2.3.1-5, established the maximum length. The favored cargo bay arrangement is shown in Figure 4.2.3.1-6.

Figure 4.2.3.1-5

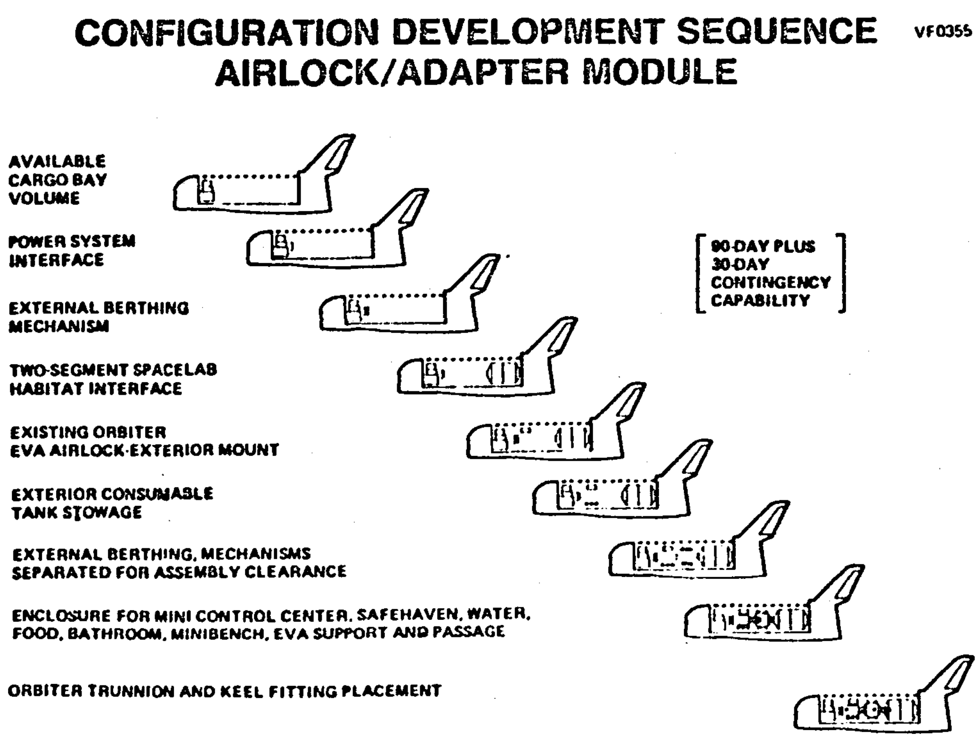

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Figure 4.2.3.1-6

CARGO BAY ARRANGEMENT AIRLOCK/ADAPTER AND TWO-SEGMENT HABITAT

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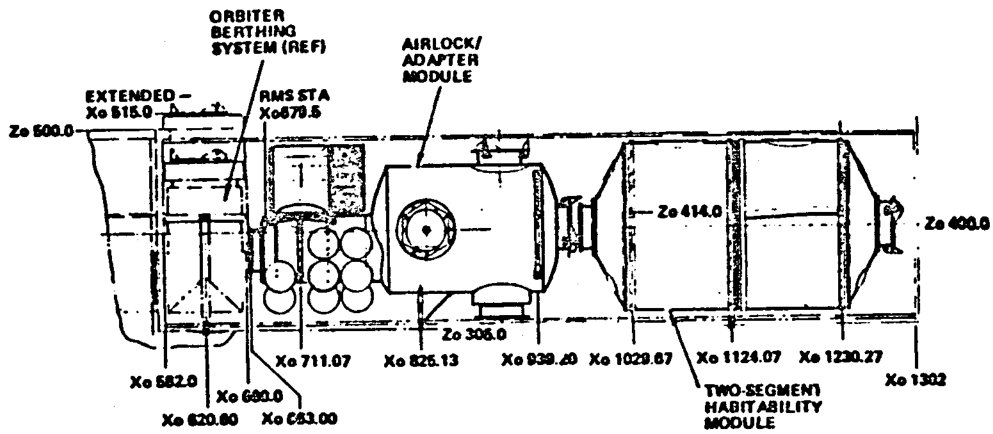

Following the sizing of each concept, an on-orbit assembly analysis was made using each concept. This analysis, shown in Figure 4.2.3.1-7, indicated that both configurations did satisfy all clearance parameters; however, the (Z) axis concept required the adapter be 5.4 m long without the (-Y) payload port. The (X) axis concept satisfied all clearance parameters with both (+Y) and (-Y) berthing ports. The (Y) port berthing is considered essential for performing routine logistics and Platform growth. With full berthing port capability, the adapter has multiple use potential. As a result, the (X) axis configuration was selected as the favored concept for further detail configuration analysis.

4.2.3.2 Habitability/Payload Module

Early in the study B, top-level functional requirements for the habitability system were generated and are listed in Figure 4.2.3.2-1. Sizing and configuration depended on the subsystem functions allocated to the module and the components required in or on the module. Initially, an habitability module concept formulation diagram, shown in Figure 4.2.3.2-2, was generated to assist in

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Figure 4.2.3.1-7

AIRLOCK/ADAPTER CONCEPT FORMULATION

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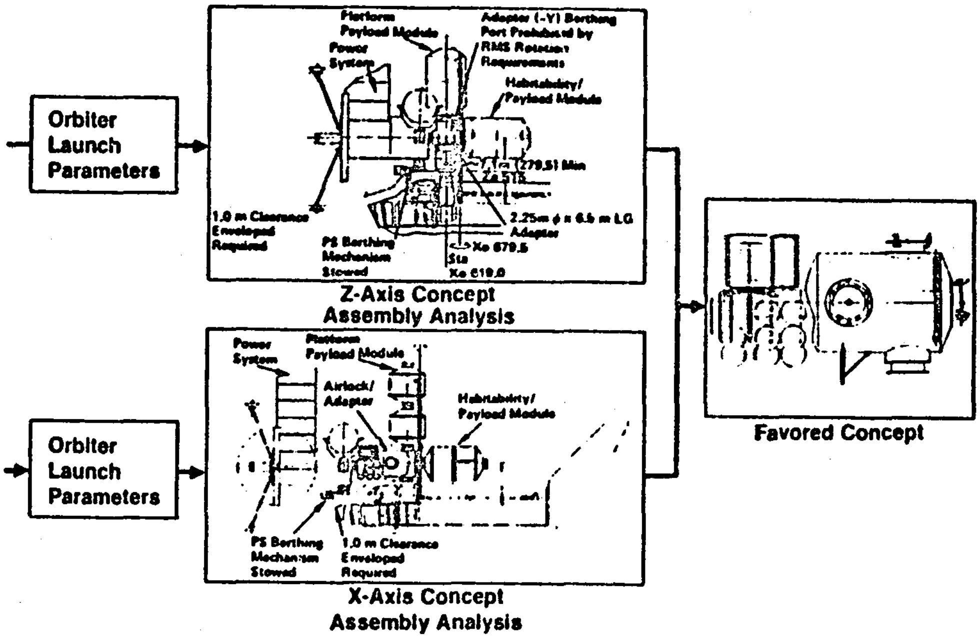

Figure 4.2.3.2-1

TOP-LEVEL HABITABILITY FUNCTIONAL REQUIREMENTS

1. **Accommodate 5th to 95th Percentile Male and Female Crew Members**
2. **Provide Windows for Earth and Space Viewing**
3. **Provide Crews With Efficient Work Areas and Private Sleep Quarters**
4. **Provide Private Washing and Waste Management Facilities**
5. **Supply Food Consisting of 65 Percent Shelf-Stable, 30 Percent Frozen, and 5 Percent Fresh Foods**
6. **Provide Refrigeration System for Unconsumed Foods**
7. **Prevent Objectionable Odors from Reaching Habitable Area**
8. **Minimize Noise in Habitable Areas; Noise Levels Consistent With Criteria in NASA SP-3006, "Bioastronautics Handbook"**
9. **Provide Exercise and Recreational Facilities**

Figure 4.2.3.2-2

HABITABILITY MODULE CONCEPT FORMULATION (ELEMENTS)

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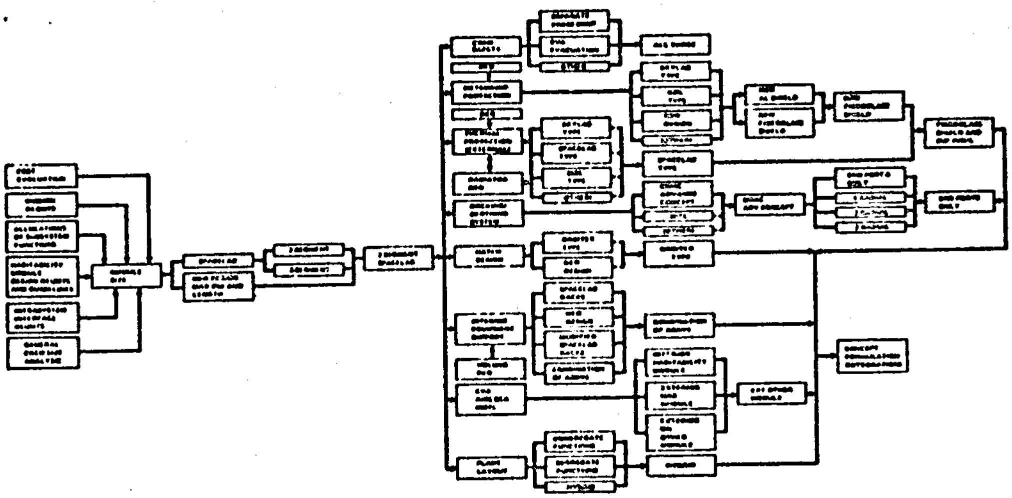

identifying the multiple choices available and establishing trade considerations required before a favored configuration could be established.

4.2.3.2.1 Two- vs. Three-Segment Spacelab - The consideration between a two-segment or a three-segment Spacelab is one such trade. The considerations in this trade are outlined in Figure 4.2.3.2.1-1

This trade was pursued early in this subtask to determine the advantages, disadvantages and building-block aspects of each.

Various analyses of volumetric relationships, impact on highly-impacted subsystems, such as the environmental control and life support system (ECLSS), crew size options and mission objectives. Figure 4.2.3.2.1-2 developed to highlight the relationship of the crew size (resident in a two- or three-segment Spacelab module) vs. available payload racks. Note that for a basic crew of two or three in a two-segment module there are 12 to 18 hours of

Figure 4.2.3.2.1-1

HABITAT AND PAYLOAD MODULE CONFIGURATION TRADES

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1- vs 2- vs 3-Segment Spacelab Modules

vs vs

Requirements

- Payloads
- Crew Quarters
- Daily Traffic
- Logistics Traffic
- Operations Control
- Habitability
- Cost

1-Segment (Short Module)

- Good For Dedicated Use (Payloads or 2-Man Habitat)
- Minimal Element (Minimal Concept Base)
- Minimal Use/Port (Constrains Total Use Factor)
- 3-m-Long Free Volume (Marginal, Ref Celentano: Crew of 3)
- Least Efficient Use of Shuttle Cargo Bay

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2-Segment (Long Module)

- Possible Dedicated or Joint Use (Payloads and Habitat)
- Largest Standard Module
- 6-m-Long Free Volume (Adequate, Ref Celentano: Crew of 3)
- Medium Use of Port
- Medium Efficiency Use of Cargo Bay

3-Segment (New, Extra-Long Module)

- Extensive Modifications to Utility Installations
- Borderline as to Crew Crowding
- 9-m-Long Free Volume (Adequate, Ref Celentano: Crew of 4 to 5)
- Too Big For Payload Dedication
- Congregates Great Variety of Equipment/Activities (Environment?)
- Maximum Use of Port
- Most Efficient Use of Shuttle Cargo Bay Space

Figure 4.2.3.2.1-2

EXPERIMENT VOLUME – CREW SIZE RELATIONSHIPS*

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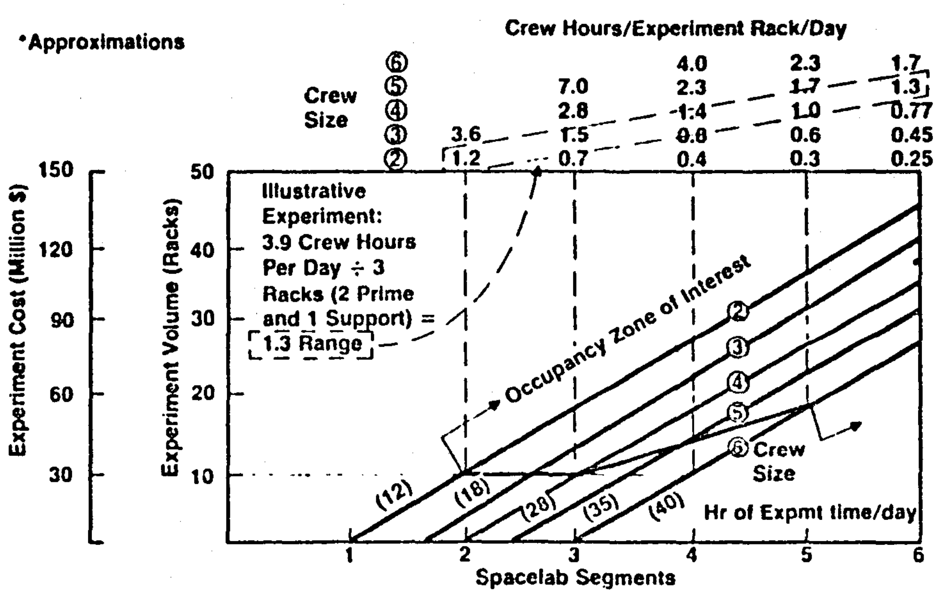

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experiment or payload time available per day with five to ten racks of controls, payload and support equipment to occupy such time. This was believed to be the range of interest for an initial Platform activation activity from an occupational standpoint. Also considered here was the assumption that the crew activities dispersed in dedicated payload modules as well as the central adapter (and in a logistics module) would minimize the need for large volumes in the habitat.

Figures 4.2.3.2.1-3 and -4 illustrate the layouts of two- and three-segment Spacelab habitats. The two-segment layout is based on the waste management facility being located in the central module; a design assumption based on the negative experiences of Skylab crews with "too close" a waste facility, i.e., human and equipment noises, odor, etc.

Figure 4.2.3.2.1-3

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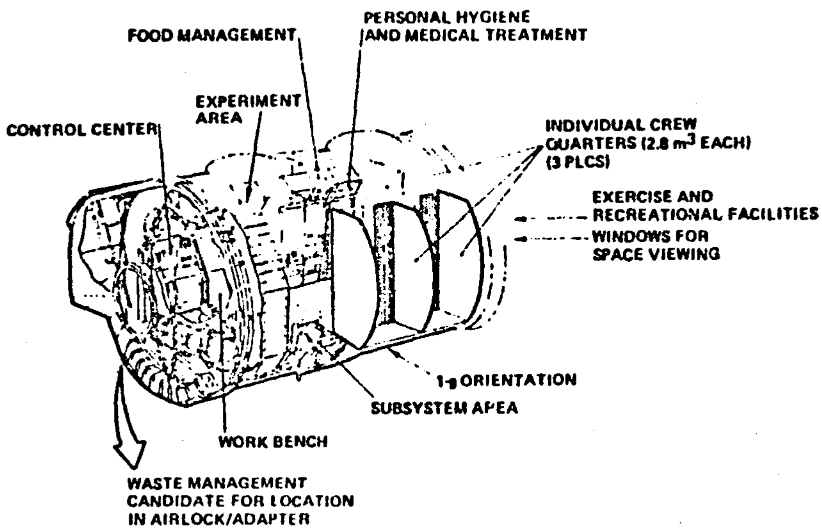
INTERIOR HABITABILITY ARRANGEMENT DESIGN FEATURES



Considerations

- Crowding — Minimal (Crew Mostly Dispersed in Habitat, Other Modules, or Asleep)
- Experiments — Only Nominal Capability in Habitat Area to Minimize Environmental (Noise, Odor, Motion) Impact on "Home" Area

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Figure 4.2.3.2.1-4

HABITABILITY MODULE (INTERIOR LAYOUT)

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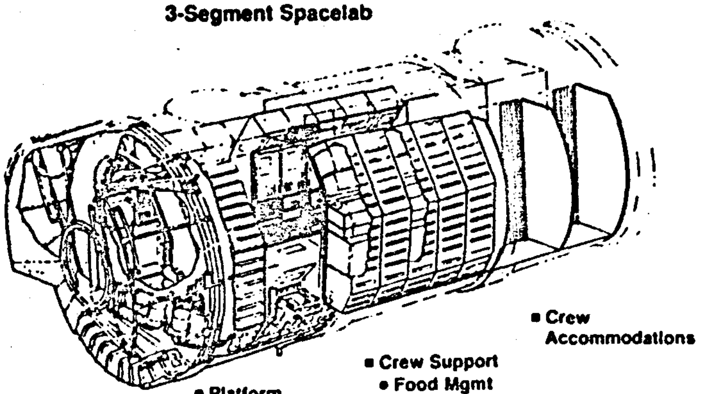

It was also believed at this point in the study that the three-segment approach represented ostensibly a "new vehicle" development because of all the subsystem impacts involved in adding one segment to a standard two-segment Spacelab. The ECLSS is particularly impacted by such a segment addition as is described shortly. Thus, from an overall configuration crew, subsystem and programmatics standpoint, it was concluded that the smaller, more standard two-segment approach provided more operations, growth and cargo bay loading flexibility and overall less development cost than the two-segment approach. Several subsystem factors also entered into the decision process

The ECLS subsystem impacts of stretching Spacelab to three segments is defined here.

A survey was made of the ECLS equipment list and a qualitative assessment was made of the impact. The results are summarized in Figure 4.2.3.2.1-5. About one-third of the assemblies are not expected to be impacted in a significant manner. Examples of these types of items are condensate separators and processors and water system assemblies.

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Figure 4.2.3.2.1-5

SPACELAB ECLS SUBSYSTEM IMPACTS OF
THIRD SEGMENT

ASSEMBLY	THIRD SEGMENT IMPACT
CABIN FAN ASSEMBLY	INCREASED VENTILATION REQUIREMENTS
CONDENSING Hx	IMPROVES PERFORMANCE (REDUCED SPIKES)
CO_2 CONTROL	IMPROVES PERFORMANCE (REDUCED SPIKES)
CONDENSATE SEPARATOR	NONE
CONDENSATE PROCESSOR	NONE
CONDENSATE STORAGE AND DUMP	NONE
CONTAMINANT CONTROL	IMPROVES PERFORMANCE (REDUCED SPIKES)
INTERCHANGE CIRCULATION	LITTLE
ODOR AND CABIN TEMPERATURE CONTROL	IMPROVES PERFORMANCE (REDUCED SPIKES)
DUCTS	LONGER RUNS REQUIRED - PERHAPS SIZE INCREASE
O_2 AND N_2 TANKS	SMALL INCREASE REQUIRED
O_2 AND N_2 FILL AND RELIEF	NONE
O_2 (N_2 CONTROL PANEL)	SLOWER RESPONSE REQUIRED
RELIEF VALVE ASSEMBLY	REDUCED PERFORMANCE (HIGHER CABIN VOLUME)
SENSOR PANEL	SLOWER RESPONSE REQUIRED
LINES AND DISCONNECTS	NONE
WATER PUMP PACKAGE	POSSIBLE INCREASE IN PRESSURE DROP
COLD PLATES	MORE MAY BE REQUIRED
LINES AND DISCONNECTS	MORE MAY BE REQUIRED
AVIONICS FAN ASSEMBLY	INCREASED FLOW REQUIREMENTS POSSIBLE
AVIONICS HEAT EXCHANGER	INCREASED PERFORMANCE MAY BE REQUIRED
DUCTING	MORE REQUIRED IF RACKS IN THIRD SEGMENT
WATER TANKS	NONE
WATER DISTRIBUTION	MORE LINES MAY BE REQUIRED
WATER MONITORING	NONE

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Performance is expected to improve in about one-fourth of the items because of the larger cabin volume which will act as a capacitance for humidity, CO_2, and contaminants. Therefore, smaller spikes will be noted thereby aiding performance of CO_2 control, condensing heat exchanger, contaminant control and composition control assemblies.

Depending upon the type design of installed equipment, the remaining ECLSS assemblies may perform at lower levels or even require modifications. A key consideration is amount, location and type of equipment installed. An example is the avionics loop which may be inadequate if rack-mounted equipment requires air cooling in the third segment. This condition would result in less total avionics loop cooling. Figure 4.2.3.2.1-6 shows several possible fixes which increase amount or size of hardware. A better solution is to use water loop cooling for third segment equipment because of reduced impacts. Higher water loop pressure drop can be accommodated by using Orbiter pumps and larger line sizes. Some air flow still might be required in the racks to facilitate smoke detection as in the Spacelab design.

Figure 4.2.3.2.1-6

POSSIBLE IMPACTS OF ADDING THIRD SPACELAB SEGMENT-AVIONICS COOLING LOOP

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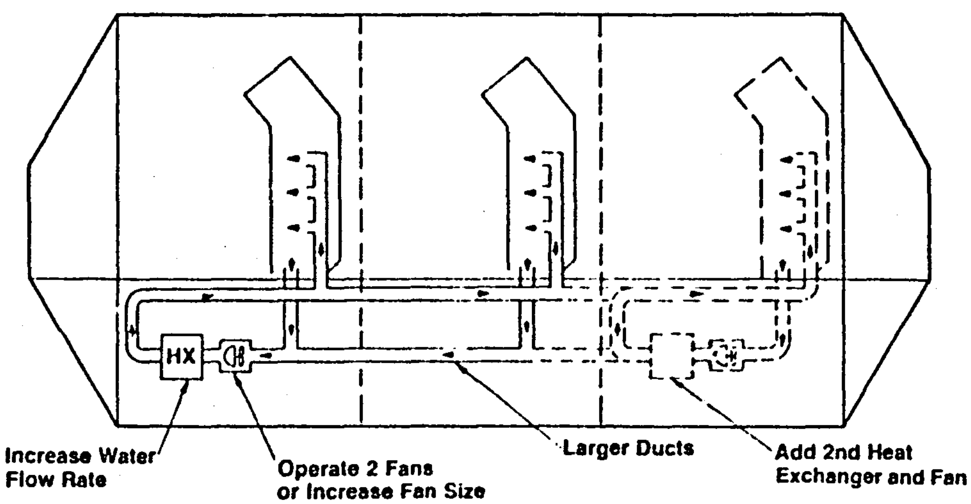

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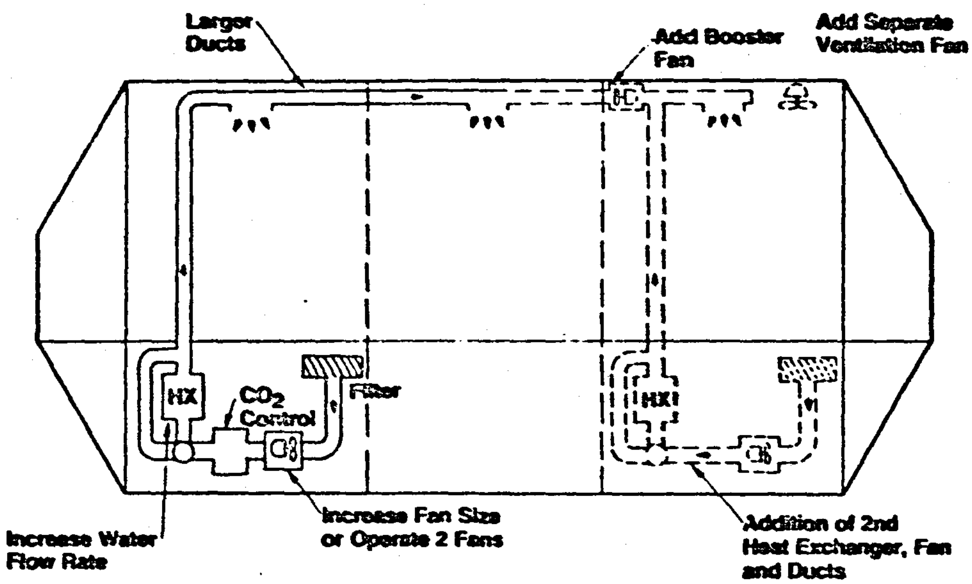
Atmosphere ventilation will also be impacted because the minimum air circulation rate must be maintained in a larger volume. Figure 4.2.3.2.1-7 shows several options which include hardware modifications or additions. Increased total atmosphere cooling loads would result in higher cabin temperatures or increased heat exchanger performance requirements.

Figure 4.2.3.2.1-7

POSSIBLE IMPACTS OF ADDING THIRD SPACELAB SEGMENT-ATMOSPHERE VENTILATION AND COOLING



4.2.3.2.2 Internal Arrangement - Following the selection of the two-segment Spacelab as the basic module, the decision process continued, as shown earlier on the formulation diagram (Figure 4.2.3.2-2). The inherent flexibility of the Spacelab permits selective rearrangement of internal components to accommodate crew requirements, payload volume requirements, subsystem volume allocations and the results from the formulations analysis.

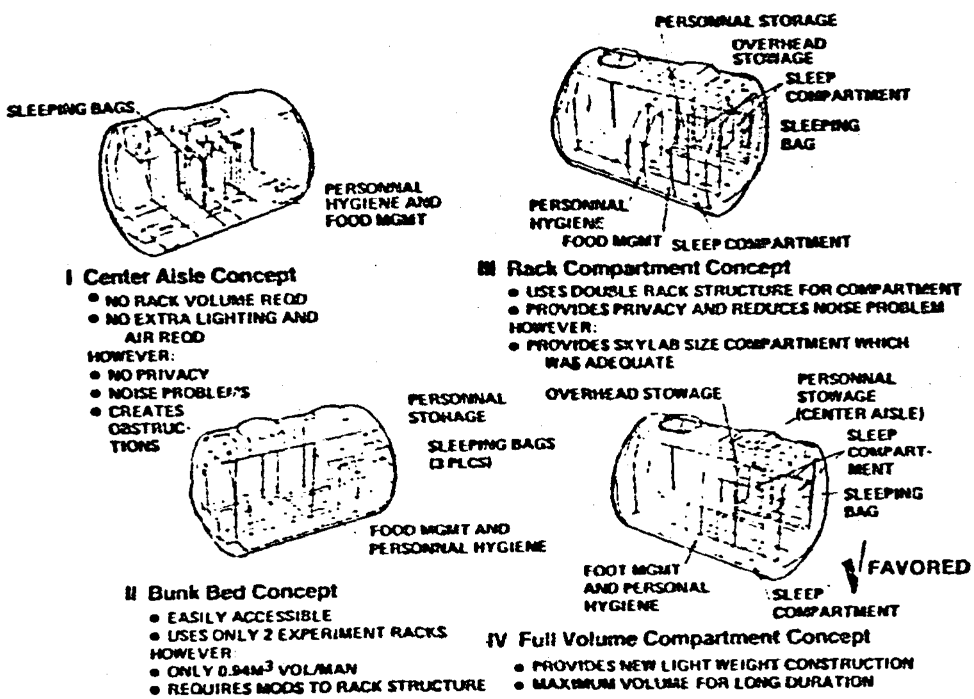
Our major area of internal flexibility is crew habitations. For long-term missions, the crew must be provided with sleeping provisions, waste management system, personal hygiene system, trash management system, food, drink, entertainment equipment, restraints, clothing. In this study we have considered crews of three or four for periods of up to 90 days with an additional 30 days contingency in the event that the Orbiter is delayed.

Various arrangements are conceivable for providing sleeping provisions within the Spacelab. Four significantly different approaches were studied. They are shown in Figure 4.2.3.2.2-1. Of the four evaluated, the full volume compartment concept providing 2.8 m^3 of volume each, is favored as best fulfilling the following general requirements:

- Provide private maximum size sleep quarters.
- Provide stowage compartments for each crew man.
- Provide soundproof and lightproof padding.
- Provide cooler atmosphere within sleep compartment.
- Provide adjustable lighting.
- Provide maneuvering aids, as required, such as toe rails, hand and body restraints.

Figure 4.2.3.2.2-1

HABITABILITY MODULE — SLEEPING ACCOMMODATION CONCEPTS



Waste management and hygiene functions were also a major internal area of concern. The Skylab design combined both the waste management and hygiene functions in a single compartment with a combined free volume of 3.57 m^3 (126 cubic feet). This was satisfactory for three crew members for 85 days, but interference between crew members during both functions simultaneously led to their suggesting separate compartments. Also, Skylab crews expressed desire to have the waste management compartment some distance from the sleeping compartments to reduce disturbing noise levels. As a result, the favored concept places the waste management system in the adapter and the personal hygiene in the habitat.

A Skylab-type food management system was selected and occupies a volume of approximately 1.083 m^3 (38 ft^3). This galley food storage was sized to accommodate up to 14 days of meals for three crew members with an additional 0.418 m^3 (14.758 ft^3) of frozen food provisions.

The favored interior arrangement, accommodating three crew men, will provide two double racks (rack 3 and 4) for incorporation of mission payload equipment. A complete detailed description of the favored habitability/payload module is presented later in Section 6, Recommended Concept Summary.

4.2.3.2.3 Crew Size Selection - Crew size for MSP was determined by consideration of those factors shown in Figure 4.2.3.2.3-1. The primary influencing factors were manhour capability, skill mix distribution and number of shifts needed.

The net manhour capability, as a function of crew size, is shown in Figure 4.2.3.2.3-2. This is based on a Skylab-derived set of activities for a basic eight-hour work day per crewman. Station operations were assumed at seven manhours per day based on Skylab. The net payload operations time could be increased by scheduling a 10-hour per man work shift.

The MOSC Study, which used a detailed data base of payload requirements, had mission manhour requirements as shown in Figure 4.2.3.2.3-3. A four-man crew was selected on MOSC. The types of MOSC payloads are not unlike those planned for MSP, as shown in Figure 4.2.3.2.3-4. Those payloads with larger crew

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Figure 4.2.3.2.3-1

CREW SIZE CONSIDERATIONS

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- Man-Hour Capabilities
- Skill Mix
- Work-Rest Cycles
- Volume
- Configuration Layout
- Program History
- Logistics
- Cost Factors

Figure 4.2.3.2.3-2

MAN-HOUR CAPABILITIES

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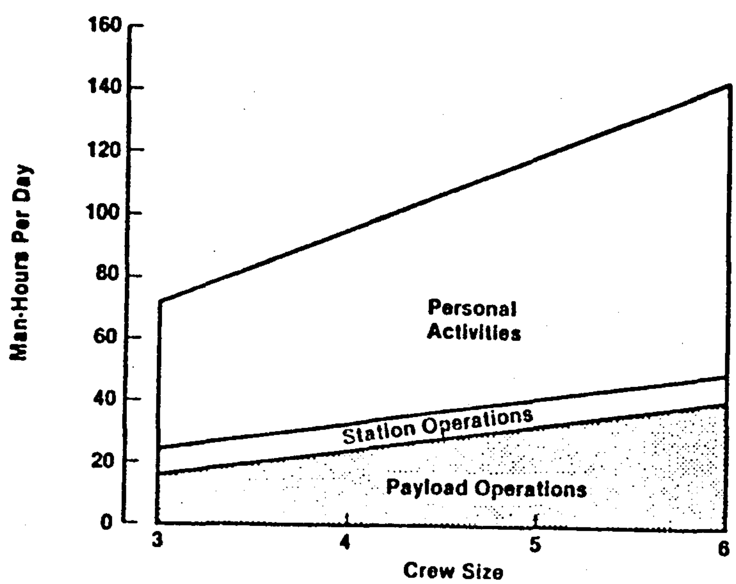

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Figure 4.2.3.2.3-3

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CREW SIZING — MOSC

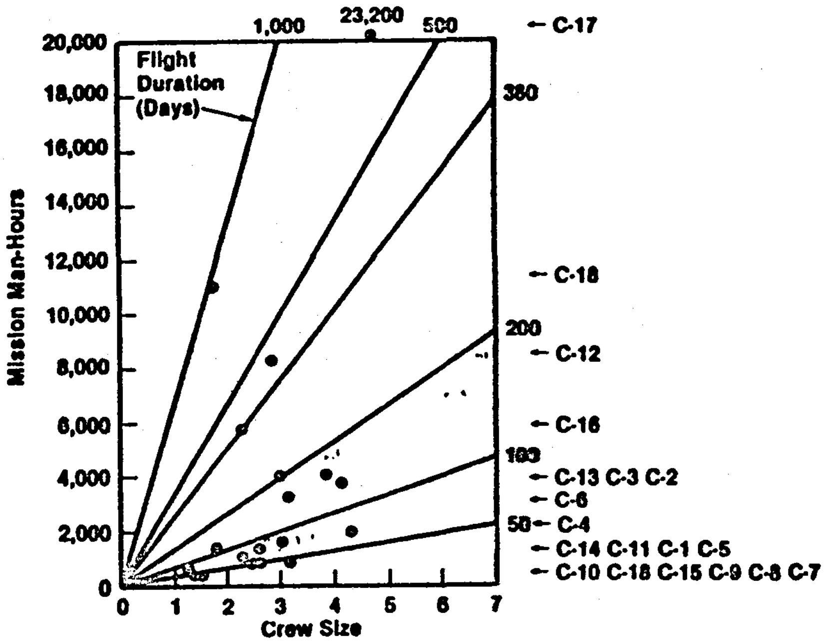
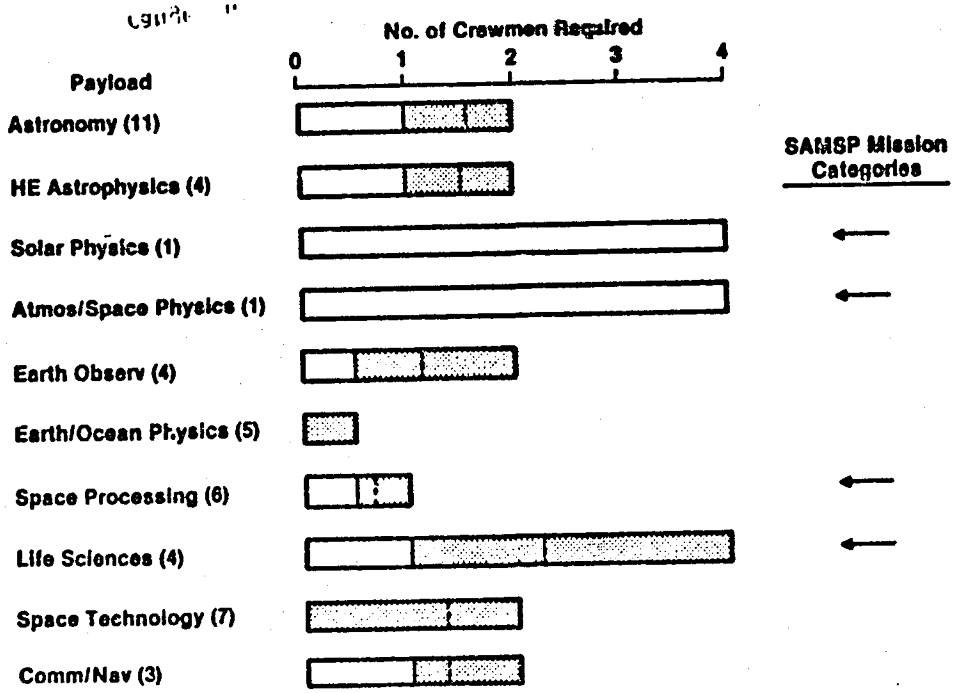


Figure 4.2.3.2.3-4

CREW REQUIREMENTS — MOSC STUDY



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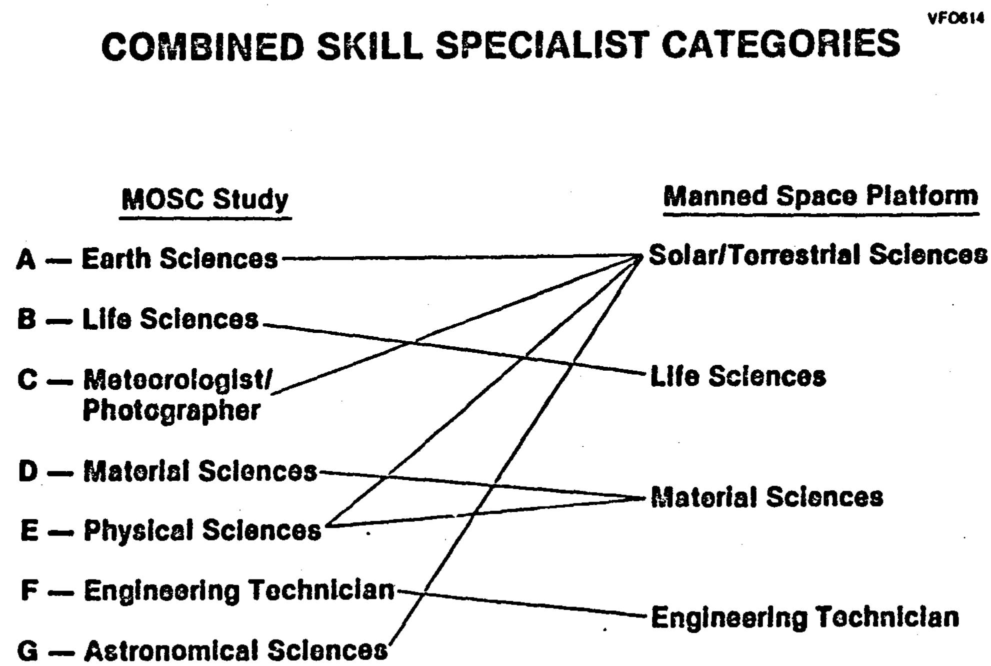
requirements on MOSC are also the crew that were selected for emphasis on MSP. The skill categories that were derived for the MOSC Study, Figure 4.2.3.2.3-5, were compared to the MSP needs. Four skill combinations would suffice.

Figure 4.2.3.2.3-5

COMBINED SKILL SPECIALIST CATEGORIES



Crew work rest cycles were analyzed for one- and two-shift operations. Figure 4.2.3.2.3-6 shows the potential for a three- and four-man crew. A three-man crew would allow a single-shift operation or a split-shift operation. Four-man would allow a two-man, two-shift schedule giving payload coverage for over 12 of the 24 hours in a day. These were based on concurrent sleep periods, found to be desirable from Skylab experience.

The volumetric needs of a three- or four-man crew are satisfied with a two-segment module and the adapter volume as shown in Figure 4.2.3.2.3-7. Habitability module layouts for three and four men are shown in Figures 4.2.3.2.3-8 and 4.2.3.2.3-9. Figure 4.2.3.2.3-10 shows the arrangement for a two-man crew with two others in a separate module. The number of payload control racks in the module for given crew sizes are shown in Figure 4.2.3.2.3-11. The

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Figure 4.2.3.2.3-6

CREW WORK/REST CYCLES

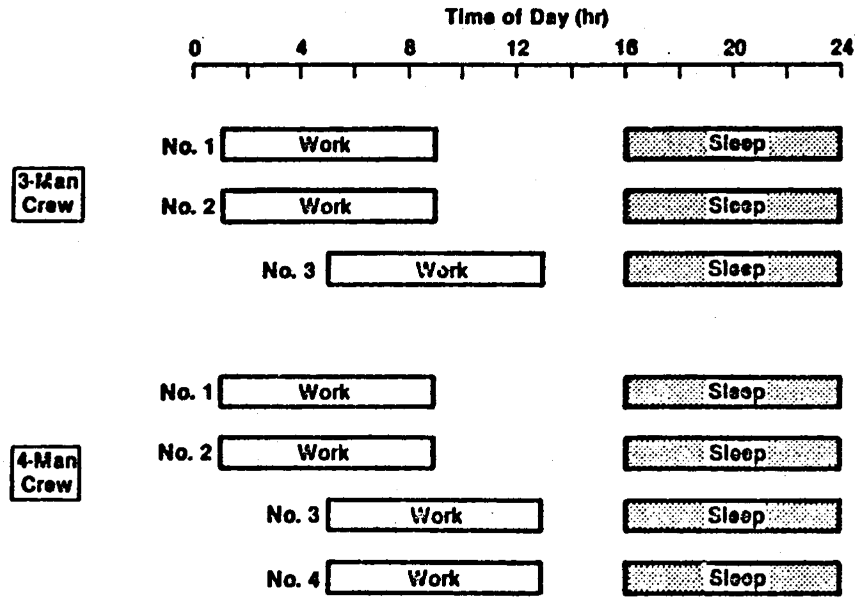

Figure 4.2.3.2.3-7

FREE VOLUME

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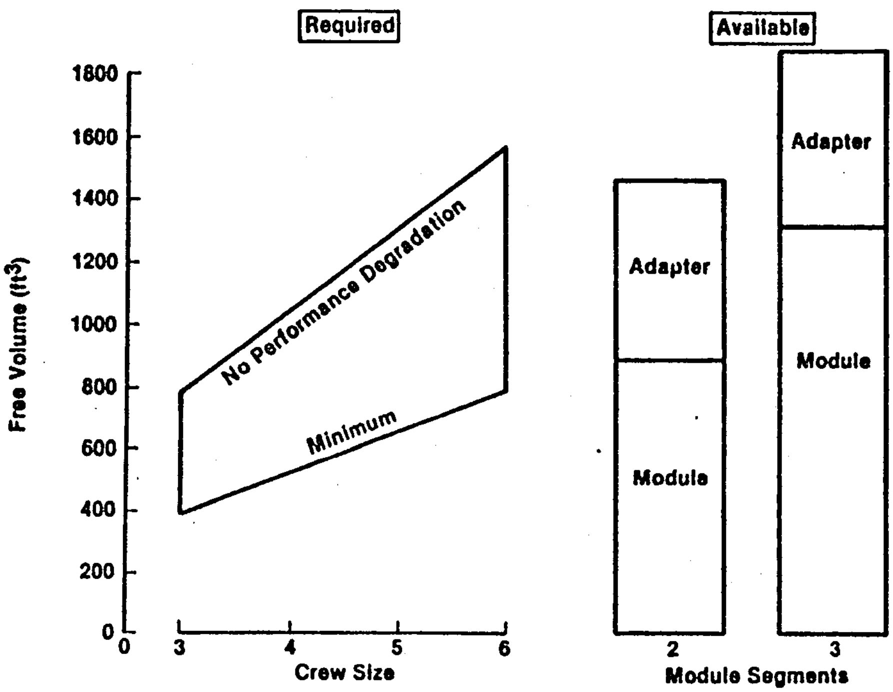

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Figure 4.2.3.2.3-8

3-MAN HABITABILITY MODULE

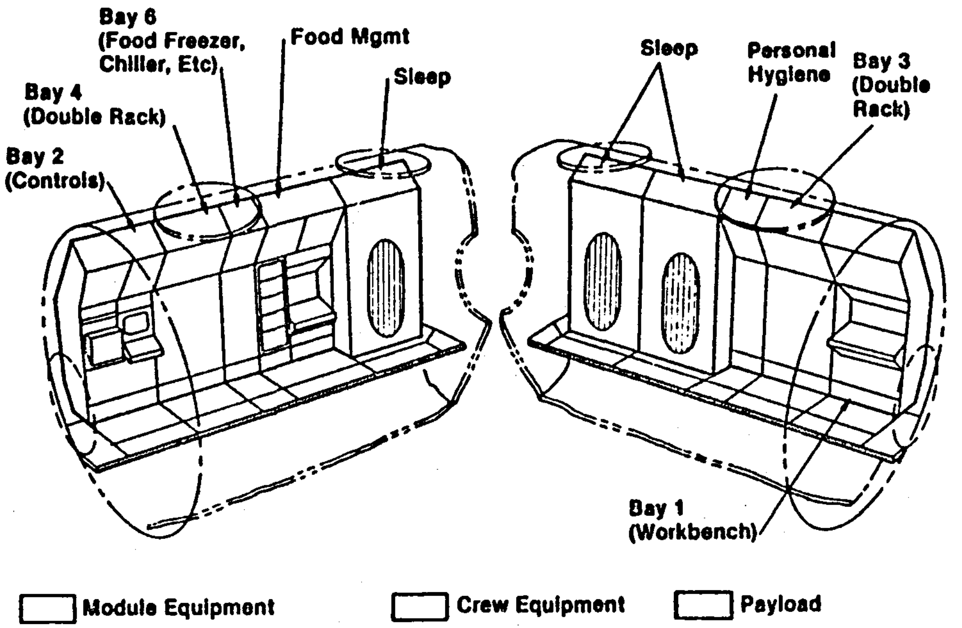

Figure 4.2.3.2.3-9

4-MAN HABITABILITY MODULE

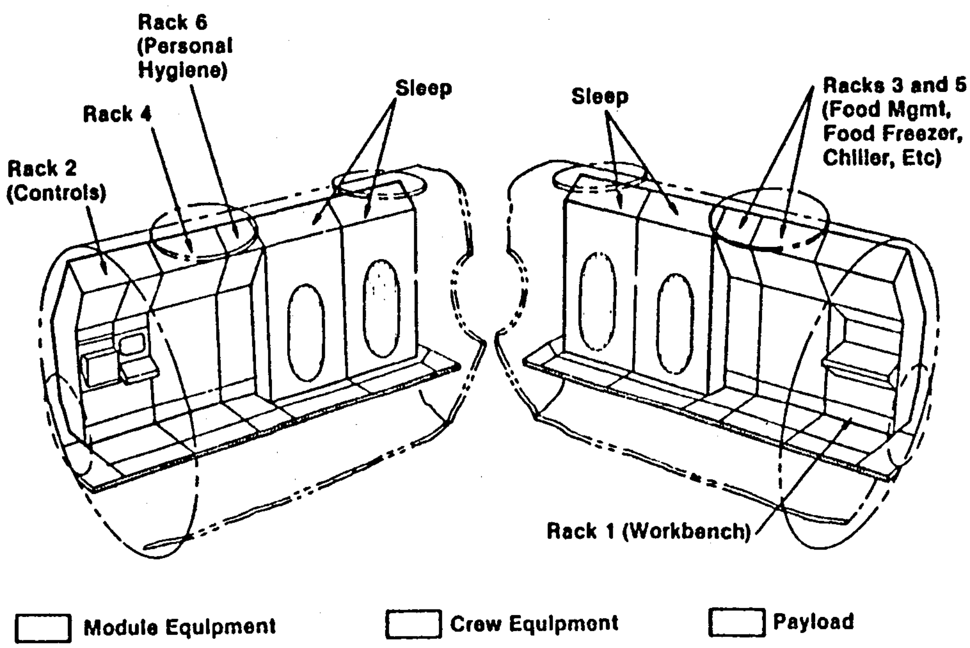

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Figure 4.2.3.2.3-10

2 + 2-MAN HABITABILITY MODULE

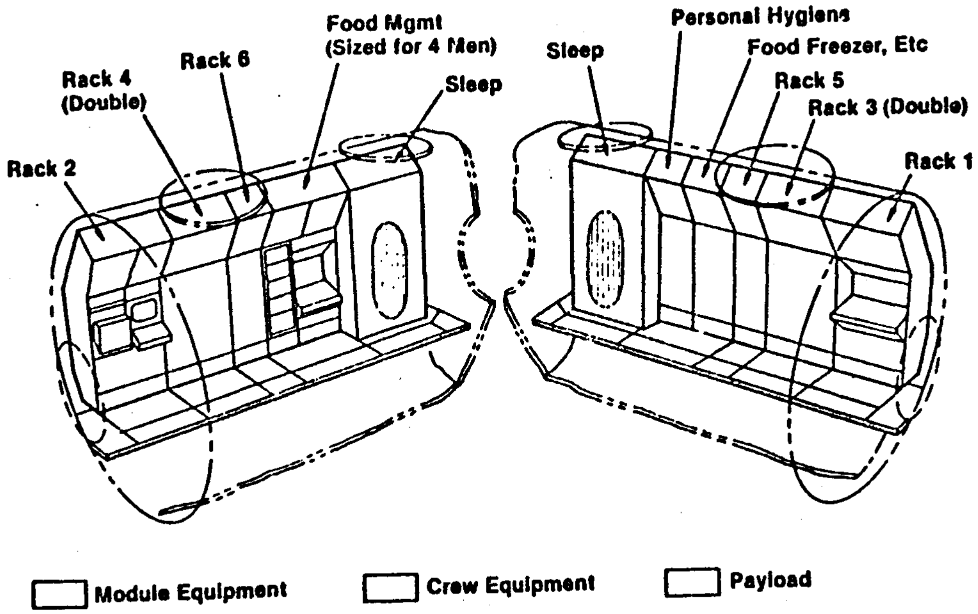

Figure 4.2.3.2.3-11

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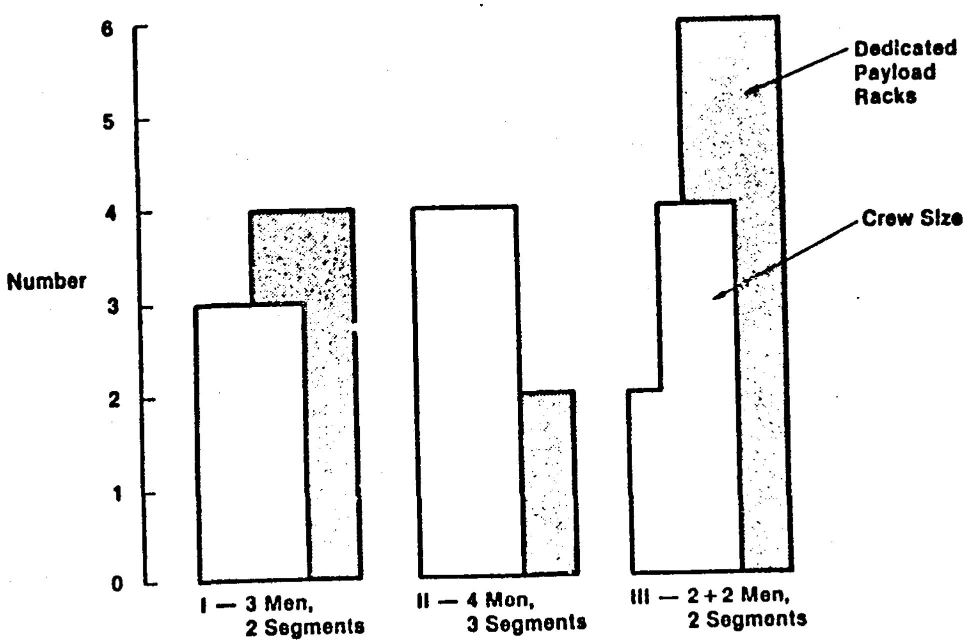
PAYLOAD
RACKS/CREW — HABITABILITY MODULE



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2 + 2-man option provides a greater area for payload racks in the habitability volume.

The logistics needs per 90 days as a function of crew size are shown in Figure 4.2.3.2.3-12. Each crew addition adds about 2000 lb of logistics per 90 days. Cost factors that would increase with crew size are listed in Figure 4.2.3.2.3-13. These would need to be evaluated before a final crew size selection could be made.

Historically, the crew size on past systems has varied from one to four as shown in Figure 4.2.3.2.3-14. MOSC, which was nearest to the characteristics and capabilities of MSP, had a suggested four-man crew.

Figure 4.2.3.2.3-12

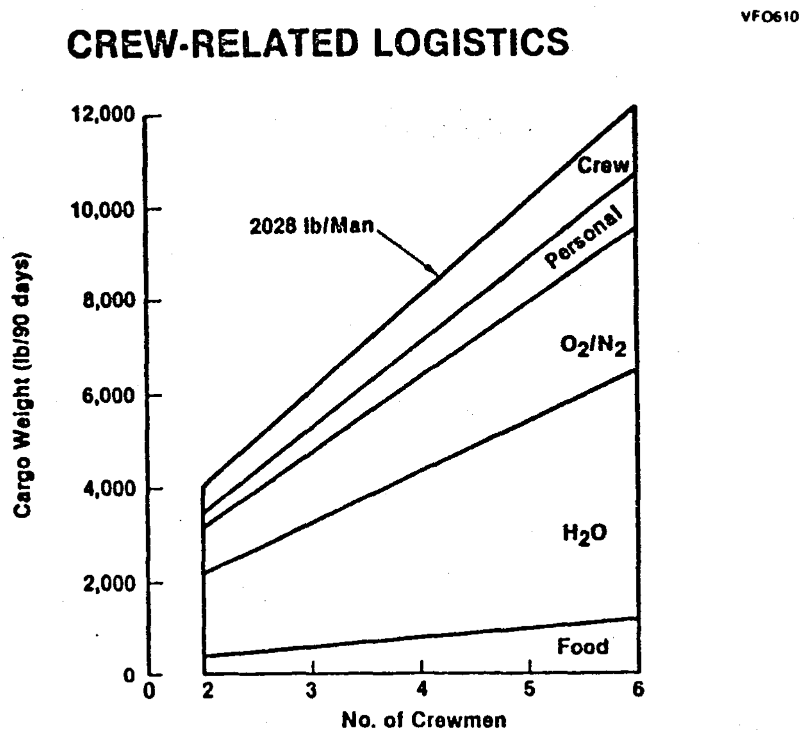


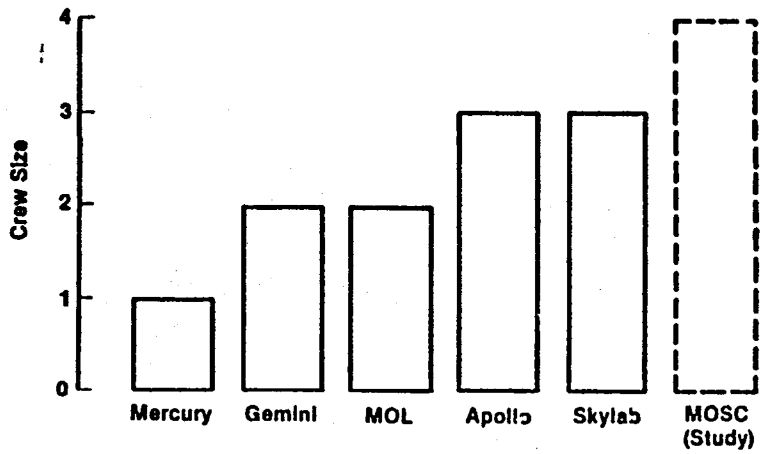
Figure 4.2.3.2.3-13

CREW SIZE COST FACTORS

- Training
- Ground Facilities
- Habitation
- Logistics
  - Rotation
  - Resupply

Figure 4.2.3.2.3-14

CREW SIZE HISTORY



In summary, the crew size factors are illustrated in Figure 4.2.3.2.3-15. Based on these data, a four-man crew is recommended because of the greater manhours per day, the better distribution of skill needs and the ability to maintain a two-shift operation with coverage up to 20 hours per day if needed.

Configuration candidates that resulted from this analysis are shown in Figure 4.2.3.2.3-16. A three-man crew in a two-segment module is the first candidate. The other two are for a four-man crew with a three-segment module and with a two-segment module augmented by a smaller module, i.e., two-man for activation with a four-man capability thereafter.

Figure 4.2.3.2.3-15

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CREW SIZE SUMMARY CONSIDERATIONS

	3 Men	4 Men
Man-Hour Capabilities	30 Hr/Day	$\boxed{\text{40 Hr/Day}}$
Skill Mix	Increased Cross Training	$\boxed{\text{1 Skill Specialist Category/Person}}$
Work Rest Cycle	12 Hr/Day Coverage Single Shift	$\boxed{\text{20 Hr/Day Coverage 2 Shift Capability}}$
Volume	2 Segment Adequate	2 Segment Adequate
Configuration Layout	Single Module Preferred	Split Module Preferred
Program History	Skylab	MOSE
Logistics	$\boxed{\text{6000 Lb/90 Days}}$	8000 Lb/90 Days
Cost Factors	–	Cost Increase

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Figure 4.2.3.2.3-16

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MSP CONFIGURATION CANDIDATES

Crew Size	Module Segments	Manning Sequence
3	2	3 → 4 → 6
4	3	4 → 6
2 + 2	2 + 1	2 → 4 → 6

4.2.3.3 Logistics Modules

The initial MSP will provide a limited amount of volume for expendables and consumables for 90 days before resupply is required. A 30-day contingency supply will also be incorporated in the initial MSP to allow for Orbiter launch flexibilities. However, the MSP is to be routinely supported through a logistics-resupply system which will provide both replenishment of existing storage, exchange of vehicle and payload equipment and additional on-orbit storage capability.

During initial phases of the study, a logistic system concept formulation diagram was prepared to assist in arriving at a recommended configuration. The diagram shown in Figure 4.2.3.3-1 was used to identify critical requirements and candidate solutions.

Initially, five methods of providing crew sustenance resupply were evaluated. These options, shown in Figure 4.2.3.3-2, involved total EVA, IVA/EVA mixture and total IVA methods. The merits of each were evaluated and a favored concept was selected to be used in the MSP concept formulation studies. The evaluation

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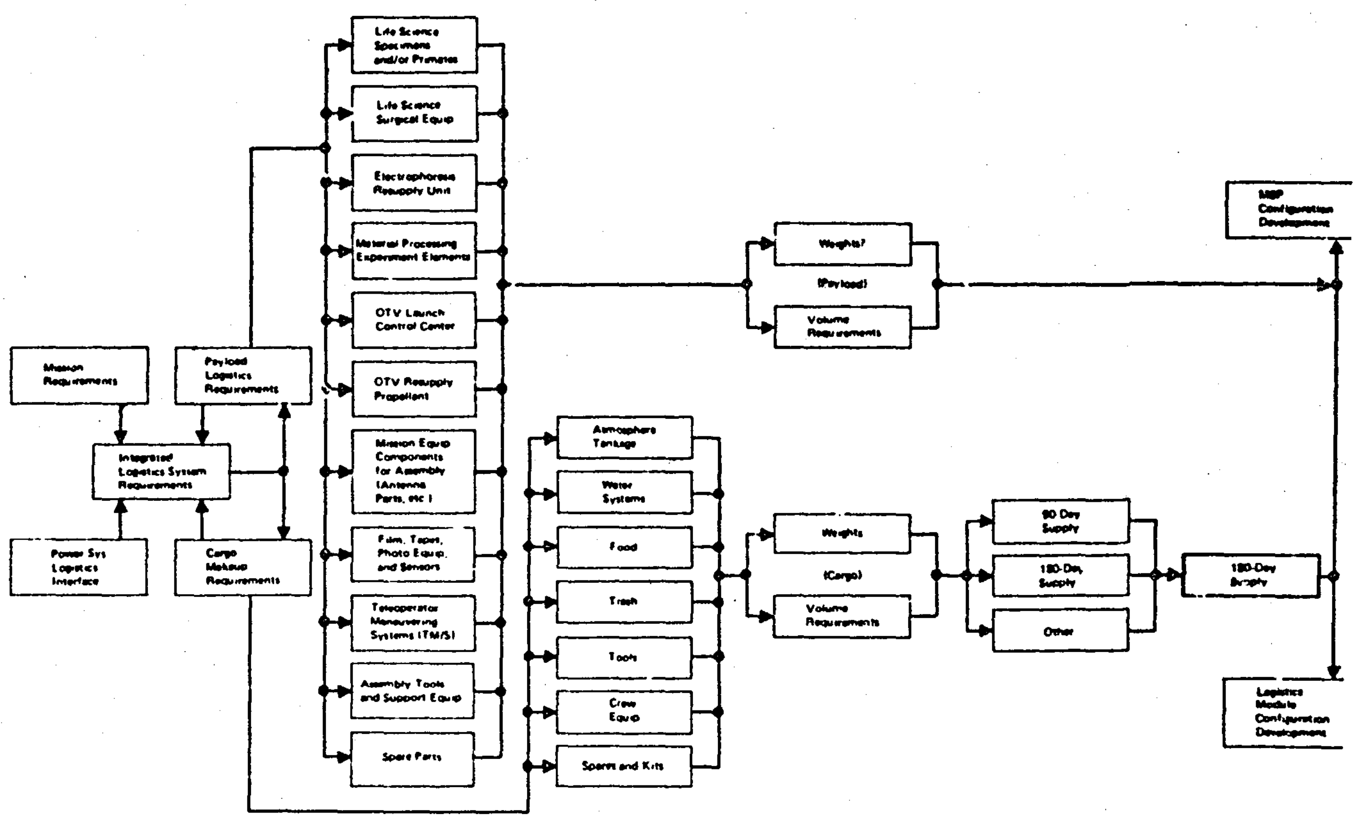

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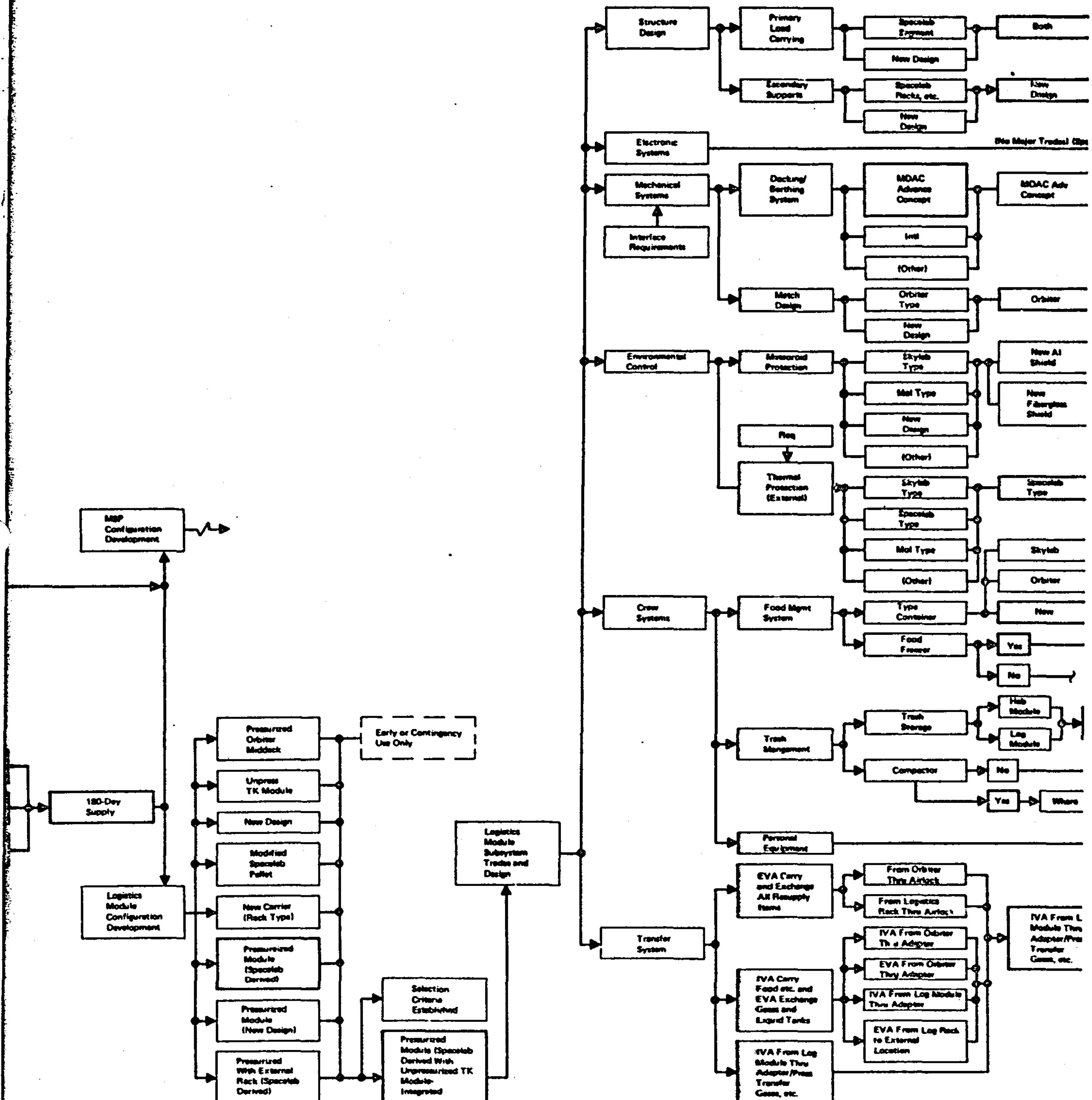

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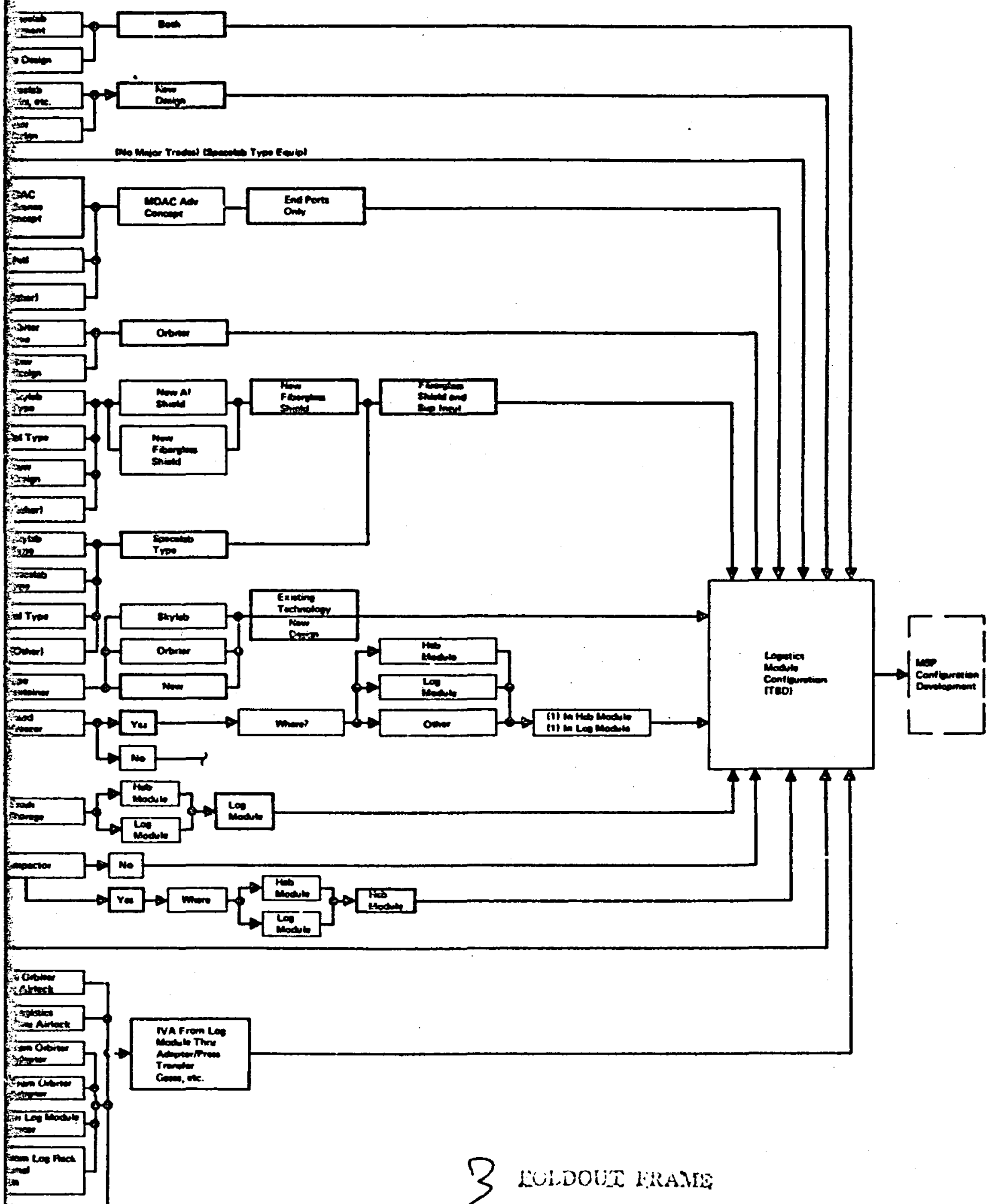

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Figure 4.2.3.3-2

PLATFORM/CREW SUSTENANCE-LOGISTICS OPTIONS

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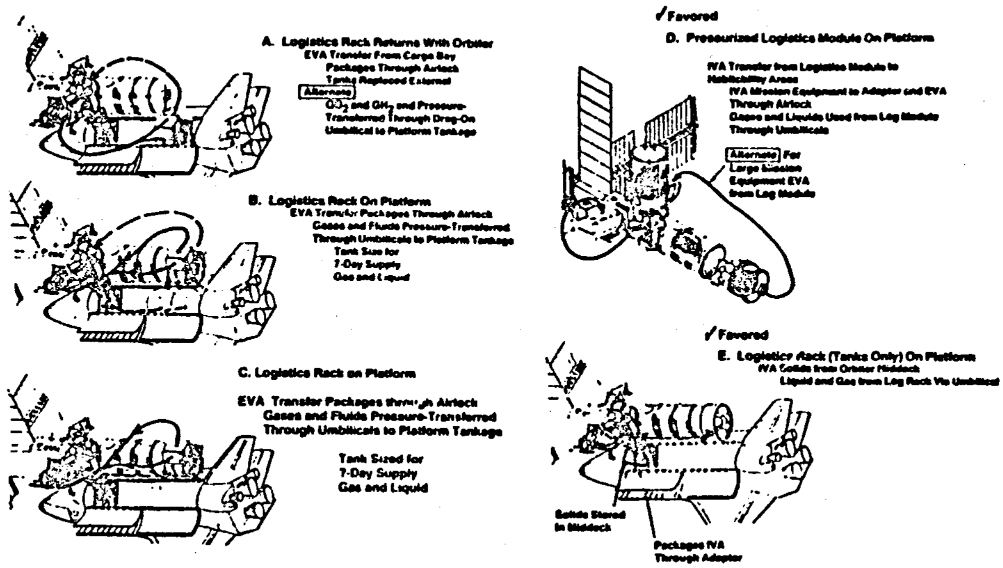

data is shown in Figure 4.2.3.3-3. The early concept involved use of a tank module sized for a 90-day resupply cycle berthed to the MSP with liquids and gases transferred via umbilicals. A 90-day supply of solid material would be stored in the Orbiter mid-deck and transferred via IVA through the airlock/ adapter into the MSP (see Figure 4.2.3.3-4). As program requirements increased, a Spacelab-derived pressurized module would be introduced and berthed to the tank module, thus becoming an integrated logistics system.

Basic MSP Logistic System - A Spacelab-derived Logistics Module with pressurized and unpressurized storage areas was selected as the favored concept for resupplying the MSP (see Figure 4.2.3.3-5). The vehicle is described in detail later in Section 6, Recommended Concept Summary. As resupply requirements were defined, it became obvious that a large pressurized volume would be required. This is partly due to the potable water requirement. Study inputs to the logistics system specify a pressurized, controlled environment for the crew water supply. As a result, the Orbiter mid-deck storage volume appears to be

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Figure 4.2.3.3-3
LOGISTICS SYSTEM EVALUATION

Configuration	Pro	Con
• Case A (EVA Transfer From Cargo Bay) (Rack Returns With Orbiter)	• Reduces Number of Mechanical Interface Operations to Be Performed By RMS • Logistics Carrier Can Be Configured to Maximize Orbiter Volume Without Consideration of MSP Impact (i.e., Spacelab, Pallet, Spacelab Module, New Rack, or New Pallet	• Special Containers Required for Food, etc • Requires All Packages Be Sized to Enter Airlock With One Crewman • Increases Chances of Damage to Airlock • Requires All Supplies to Be Offloaded Before Orbiter Return • Increases Stowage Requirements On-Board Platform • Increases EVA Total Time to Offload Supplies • Requires Tanks to Be Sized for EVA Handling and Designed for Mechanical Replacement (See Case A Alternate) • Requires Airlock Modification to Provide Tiedowns During Airlock Operation
Case A Alternate (Packages Through Airlock, Liquids and Gases Pumped From Orbiter)	• Same As Above for Case A Except Tanks Can Be Sized to Accommodate Volume Requirements and Installation Provisions Dictated By MSP Configuration	• Same As Above For Case A Except Pressure Transfer of Liquids and Gases From Orbiter Results in Scars to the Orbiter In Terms of Line Supports, Umbilicals etc. Plus Hazard to Orbiter Safety
• Case B (On-Orbit EVA Transfer Solids Through Airlock) H_2O TK Replacement Gases From Orbiter	• Enables Transfer of Solid Supplies As Needed • Reduces EVA Operations to Replace • Reduces Total Number of Tanks Required to Satisfy 5-10 Year Mission Tanks • Reduces Orbiter Stay Time	• Requires Time-Consuming EVA Operation to Resupply Platform • Special Food Containers Required • Requires EVA to Drag On Lines to Transfer Gases • Umbilical Design Complicated for EVA Manual Hookup • Uses Excessive Orbiter Volume in Addition to Logistics Vehicle • H_2O Tanks Require Design for Manual Replacement • Packages Must Be Sized to Enter Through Airlock With One Crewman, Which Limits Design • Airlock Modification Required for Tiedowns
• Case C (EVA Transfer Solids Through Airlock, Gasses and Liquid Pressure Transferred)	• Reduces EVA Time to Resupply Platform • Enables Transfer of Liquid and/or Gases As Required • Minimum Orbiter Stay Time to Resupply Platform • One Tank Design Can Satisfy Platform and Logistics System Requirements	• Requires EVA Operation to Resupply Platforms • Package Must Be Sized to Enter Through Airlock With Crewmen • Airlock Modification Required to Provide Package Tiedown During Airlock Operation • Special Food Containers Required to Provide Necessary Atmosphere
Favored ✓ • Case D (IVA Transfer of Solids, Pressure Transfer Gases and Liquids)	• Enables Crew to Restock Platform As Needed • Transfer of Gases and Liquids Can Be on an As Needed Basis Directly From Log Module If Desired • Permits Sizing of Platforms Tankage for Minimum Volume Requirements • Permits Interior of Hab/Payload Module to Be Designed With Minimum Stowage Provisions • Enables Crew to Maintain Housekeeping Procedures With Minimum Effort (Trash, etc. Can Be Taken to Log Module As Needed) • Provides Secondary Safety Shelter for Crew • Provides Protected Environment for Food, Specimens, etc • Permits Log Module to Be Used As Airlock to EVA Transfer Large Payload Items	• Increases System Requirements and Complexity of Logistic Vehicle Design to Maintain Shirt-Sleeve Environment • Increases Complicated Interfaces • Airlock May Require Mods to Permit Packages to Be Transferred To and From Experiments
Favored ✓ • Case E (IVA Solids From Orbiter Mid Deck, Liquid and Gas From Logistics Rack)	• Minimum Cargo Bay Volume Requirements • Concept Permits A Single Design Tank Module Adaptable to Large Pressurized Logistics Module	• Limited Volume Available in Orbiter Increases Logistics Flights • Packages Must Be Sized Compatible With Mid Deck Provisions • All Supplies Must Be Transferred During Orbiter Visit

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Figure 4.2.3.3-4

ESTIMATED ORBITER LOGISTICS STOWAGE VOLUME

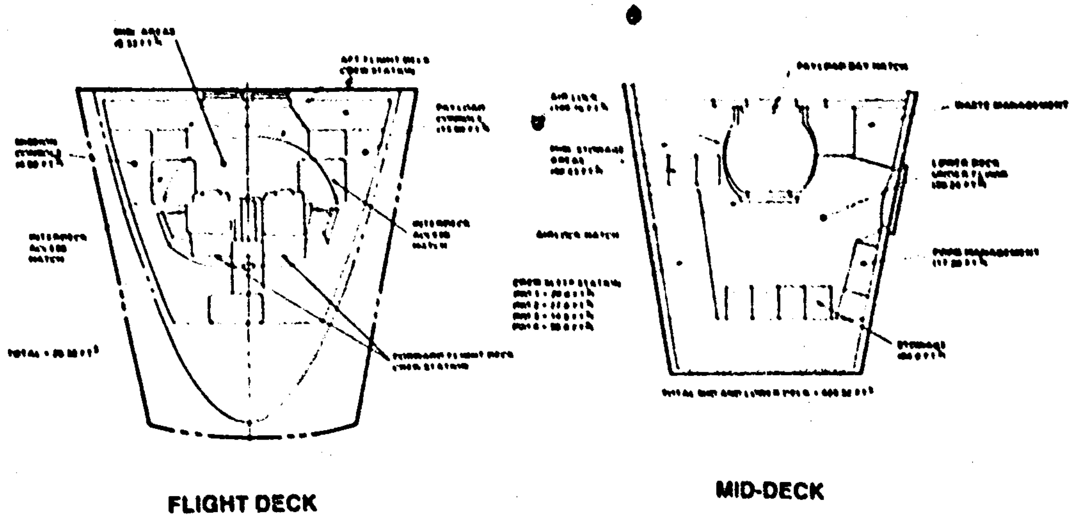

Figure 4.2.3.3-5

CONCEPT SELECTION LOGISTICS MODULE

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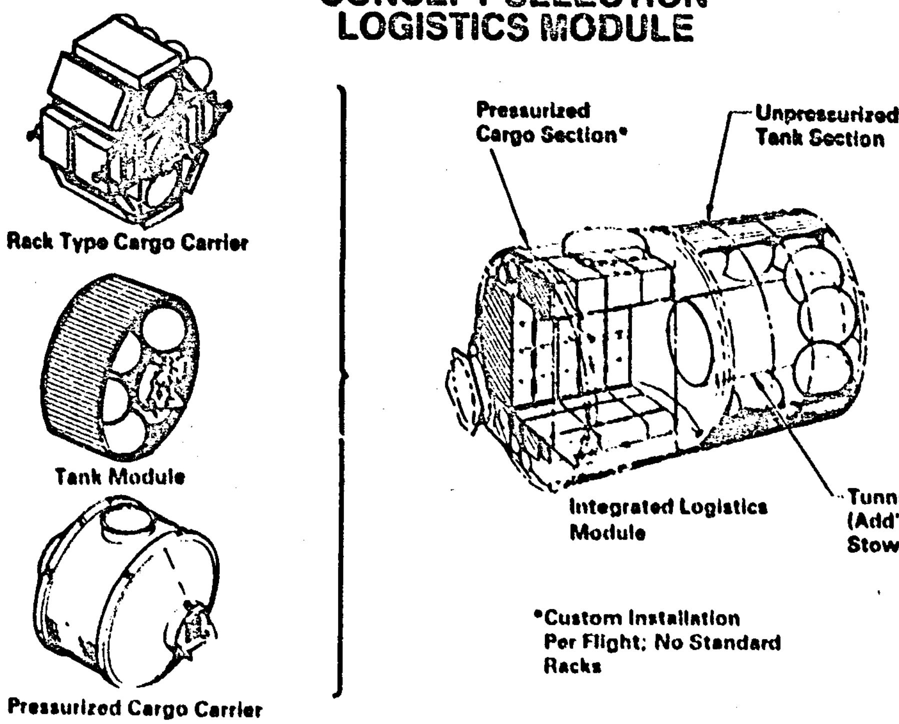

insufficient for a complete 90-day resupply and is not recommended for this purpose. Use of Orbiter bunk area for resupply stowage is not recommended since MSP crew overlap time will require use of bunks by crew members.

Current operations scenarios indicate that use of a logistic module sized for 180-day resupply cycle would minimize cargo bay volume impacts associated with resupply. Crew exchange, at 90-day intervals would be possible during resupply and/or payload launches. A 180-day logistic system minimizes cargo bay weight and volume losses due to logistics.

180-Day Logistics Requirements - The volume and weight requirements imposed on the logistic system to provide sustenance for a three-man crew over an 180-day resupply cycle is shown in Figure 4.2.3.3-6. The early MSP configuration will provide limited payload accommodation internal of the habitability module. As a result, logistic volume of 82 ft^3 is estimated as being required to completely change out this payload equipment. The trash storage volume indicated serves dual purpose since its requirement is for on-orbit storage only for returning to earth, thus it can be used for other items during delivery.

Figure 4.2.3.3-6
LOGISTICS WEIGHT AND VOLUME REQUIREMENTS - 180-DAY RESUPPLY CYCLE - THREE-MAN

	Weight (Lb)	Volume (Ft^3)
Basic Sustenance		
■ Shelf Stable Food	(3.6 Man-Day)	139
■ Frozen Food	(1.0 Man-Day)	54
■ Water	(4620)	80
■ Clothing	(1.6 Man-Day)	54
■ Personal Gear	(TBD)	6 (Est)
*■ Trash Storage (Compacted to 0.38 Ft^3 MD)	(TBD)	206
■ EVA Supplies	(TBD)	100 (Est)
■ Maint and Housekeeping Supplies	(4.0 Day)	50
■ MSP Spares	(TBD)	100 (Est)
■ ECLS Supplies	(TBD)	(TBD)
Early Payloads		
■ Life Science	(TBD)	50.0 (Est)
+ ■ Material Processing	(TBD)	32.0 (Est)
or ■ Solar-Terrestrial	(TBD)	50.0 (Est)

Logistics Module Concept

Logistics Module Design

*This Volume Can be Used for Other Purposes During Delivery to Orbit — But is Reserved for De-Orbit Trash

- Crew personal gear is transported along with the crew in the Orbiter mid-deck on a 90-day crew rotation cycle.

The crew-related items to be resupplied are as follows:

1. <u>Food - Dehydrated, Intermediate Moisture and Wet Pack</u>
   Food packages to be transferrred from the Logistics System and stored in various elements of the MSP as required. Assumptions for planning are:

   Weights: Dry food = 1.0 lb/person/day
   1.6 lb water in food weight
   Packaging = 1.0 lb/person/day
   3.6 lb/person/day

   3 crewmen X 180 days = 540 man-days
   540 X 3.6 = 1944 lbs shelf stable food

   Volume: 0.17 ft^3/3.6 lbs/man-day
   0.17 ft^3 X 540 = 92.8 ft^3 shelf stable food
   (2 ft^3 contains 12 man-days)

   Storage: We elected to use a packaging efficiency factor of 1.6. This factor is an estimate of the total volume that includes racks, shelves, etc., for storing a cubic foot of food.
   92.8 ft^3 X 1.6 = <u>148.48 ft^3</u> of storage required for an 180-day supply for 3 crewmen.

<u>Food - Frozen</u>
Frozen food is to be transferred from the Logistics System and placed into a freezer/chiller provided as part of the MSP food management system. This also requires a freezer be provided as part of the Logistics vehicle. The assumptions used for weights planning purposes are:

Weights: assume 1.0 lb/man-day = 540 lb frozen food
wt/ft^3 = 10 lb/ft^3 = 54 ft^3 frozen food

Volume: used 30 ft^3 of storage space for the 22.5 ft^3 of frozen food required for 3 people X 180 days.

(Refrigerated Food)

The refrigerator will be used to store leftovers or to thaw frozen food. Used a 10 ft^3 refrigerator. This number was based on Skylab experience.

2. Water

The MSP will be required to accept water from the logistics system by (1) replenishing onboard tanks with a transfer system, (2) replacement of onboard tankage or (3) logistics system tankage connected into the MSP water dispensing system. Tankage connected into the MSP water system is favored concept. Assumptions:

Weights: Drinking water = 1.5 lb/man-day
Rehydration water = 4.0 lb/man-day
5.5 lb/man-day

Volume: Used 28 tanks (15.5 dia X 35 lg) with a total volume of 80 ft^3.

3. Life Support GH_2 and GO_2

The MSP will be required to accept atmospheric gases in the same manner explained for water resupply. GN_2 and GO_2 tankage onboard the resupply craft connected directly into the MSP atmospheric system is the favored configuration.

4. Waste/Trash Disposal

Ultimately, the logistics system will return the waste/trash to earth. A limited volume will be available in the MSP for trash management. To increase the efficient utilization of the available volume, a compactor is recommended. Assumptions are:

Wet and dry trash compacted to 0.38 ft^3/man-day.
0.38 ft^3 X 540 man-days = 205 ft^3 storage required in Logistic module.

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5. Clothing

Personal items such as clothing, washcloths and towels are the throw-away type and will ultimately be returned to earth. Each MSP crew compartment includes storage volume for a 90-day supply of personal items with soiled elements being returned to the original storage position or placed in the trash management system. Volume assumptions are:

1.7 lb/man-day

1 crewman X 180 days = 306 lbs requiring approximately 18 ft^3 storage per crewman.

18 ft^3/man X 3 = <u>54 ft^3</u>

6. Non-consumable/Expendable Items

Initially, items such as batteries, black boxes, valves, pumps, etc., would be designed with built-in redundancy for high probability of completing the mission. However, the logistic system will be required to provide spares accommodation to support the MSP subsystems at the LRU level to maintain 90 days operation with a reliability of TBD. ECLS filters, chemicals, seals, etc., are considered scheduled replacement items and require resupply by the logistics system. Assumptions are:

Maintenance and Housekeeping Supplies

4.1 lbs/day X 180 days = 720 lbs

estimated 15 lbs/ft^3 = 720/15 = 48 ft^3 required

The wide spectrum of operations in prospect for the Manned Space Platform must be defined, scoped and evaluated for criteria on which the supporting systems are to be designed. Figure 4.2.3.3-7 outlines the types of situations and corresponding accommodation considerations anticipated. Figure 4.2.3.3-8 charts the flow of exchange or resupply items in the case of a Shuttle-tended mission. However, the same general flows apply to the case where the logistics module is removed from the cargo bay and attached to the Platform for a 180-day stay. Figure 4.2.3.3-9 illustrates the various sizes and types of equipment packages which must be accommodated in the logistics loading and unloading procedures and modules.

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Figure 4.2.3.3-7

ON-ORBIT PAYLOAD EXCHANGE PROSPECTS

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Objectives
- Efficiency in Planning and Operations
- Protection of Payloads, Crew, Platform, and Orbiter

Situation Differences
- Individual Versus Groups (Whole Module) of Payloads
- Planned Objectives Achieved/Time)
- Unplanned (Unrepairable Malfunctions) (Interim Replacement?)
- Differences in Replacement Payload (Volume or Support)

Accommodation Considerations
- Structural/Mechanical (Removal and Installation)
- Transport Mode
  - Earth to Orbit and Back
    - Individual Lockers (Cargo Bay)
    - Community Container (Cargo Bay)
    - Mid-Deck Lockers
  - Orbiter to Platform and Back
    - IVA and/or EVA
    - Transport Aids
- Power/Data/Communications/Thermal (Hookup and C/O)
- Crew (Preparation and Training)
- Payload Modularity (Disassembly in Transit)

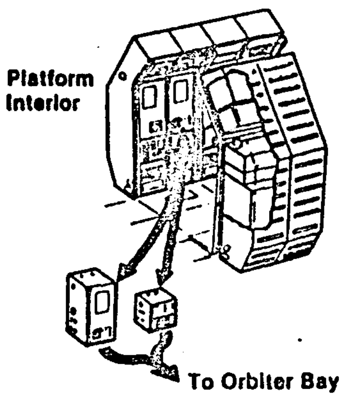

Figure 4.2.3.3-8

ON-ORBIT PAYLOAD EXCHANGE PROSPECTS

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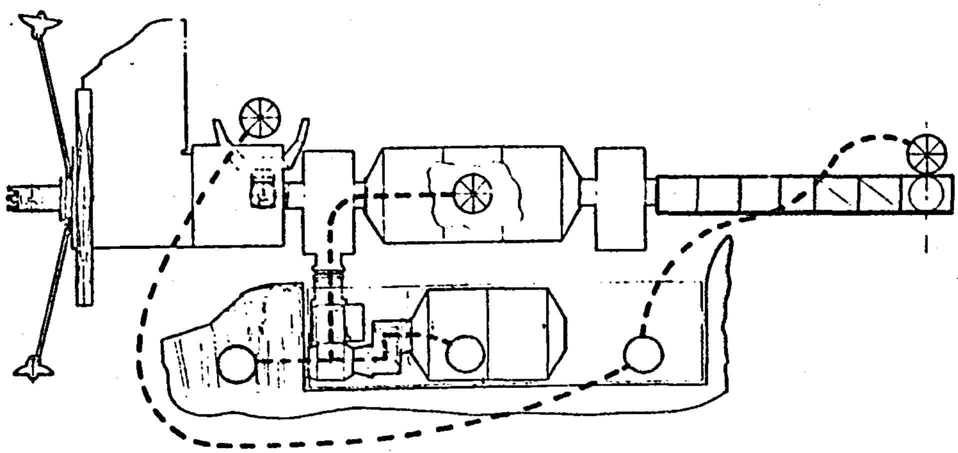

System Influences
- Size of Replaceable Unit
- Ease of Removal and Installation
- Crew Time and Aids Required
- Shipping Installation Flexibility

⊛ Payload Operating Location
◯ Payload Shipping Location
---- Relocation Route (Via RMS, EVA, and IVA)

Figure 4.2.3.3-9

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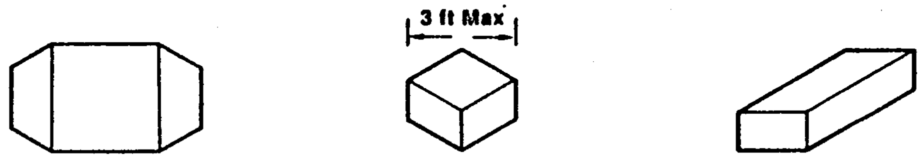
MSP EQUIPMENT CHANGEOUT OPTIONS



Module or Pallet Level	Subrack	Component
• Minimum Number of Connections	• Many Connections	• Most Connections
• Dedicated Module	• Too Small for Some Equipment	• Too Small for Some Equipment
• Minimum Crew Time/Training	• EVA for External	• EVA For External
• Simple Operations	• Complex Design	• Complex Designs
• Large Weight Penalty	• Crew Time/Training	• Much Crew Time/ Training

Interfaces

- Liquid — Quick Disconnects
- Vacuum — Shutoff Valves
- Gases — H_2, O_2, N_2, CO_2
- Structural — Captive Fasteners/ Release
- Cooling Air — Ducting
- Cables — CDMS and Power

Mission Payload Logistics - In addition to providing sustenance for the crew, the MSP logistics system must be capable of supporting the payload mission objectives. Logistics requirements for the payloads range from live primates for Life Science experiments, to OTV resupply propellant. A cursory evaluation of the type of equipment to be accommodated and type of carrier that may be involved was made to determine the impact on MSP design. This evaluation is summarized in Figure 4.2.3.3-10. The three types of carriers identified indicate three types of resupply transfer: (1) IVA transfer from the pressurized module, (2) EVA transfer from palletized experiments and (3) remote handling by the Orbiter RMS and/or an onboard manipulator. A composite configuration is shown in Figure 4.2.3.3-11 in an attempt to identify the impact and to evaluate the basic MSP configuration in terms of payload logistics. It appears that a growth version of the MSP utilizing a second adapter can provide adequate berthing accommodations; however, access to these ports is questionable and will require a detailed evaluation with specific payload elements and mission objectives.

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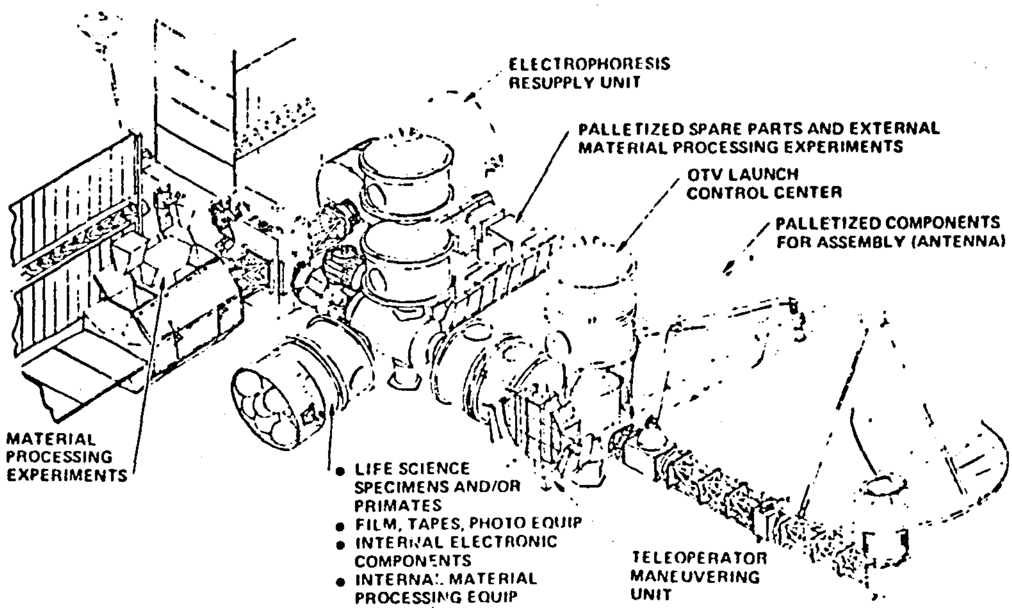
Figure 4.2.3.3-10

PLATFORM DESIGN DRIVERS FOR MISSION PAYLOAD LOGISTICS

TYPE OF EQUIPMENT TO BE ACCOMMODATED	TYPE OF CARRIER		
	CONTROLLED ENVIR (ORBITER MIDDECK OR NEW MODULE)	PALLET	SELF CONTAINED
LIFE SCIENCE SPECIMENS AND/OR PRIMATES	X		X
ELECTROPHORESIS RESUPPLY UNIT			X
MATERIAL PROCESSING EXPERIMENT ELEMENTS	X	X	X
OTV LAUNCH CONTROL CNETER	X		X
MISSION EQUIP COMPONENTS FOR ASSEMBLY (ANTENNA PARTS, ETC)		X	X
ASSEMBLY TOOLS AND SUPPORT EQUIP		X	X
OTV RESUPPLY PROPELLANT			X
SPARE PARTS FOR • POWER SYSTEM • PS REBOOST MODULE • PRESSURIZED MODULES • EXTERNAL EXPERIMENTS • EXTERNAL • STORES (LIQUIDS, GASES, ETC)	X	X X X X	X X
FILM, TAPES, PHOTO EQUIP, AND SENSORS	X		
LIFE SCIENCE SURGICAL EQUIP	X		
TELEOPERATOR MANEUVERING SYSTEMS (TM/S)			X

Figure 4.2.3.3-11

MISSION EQUIPMENT LOGISTICS COMPOSITE CONFIGURATION



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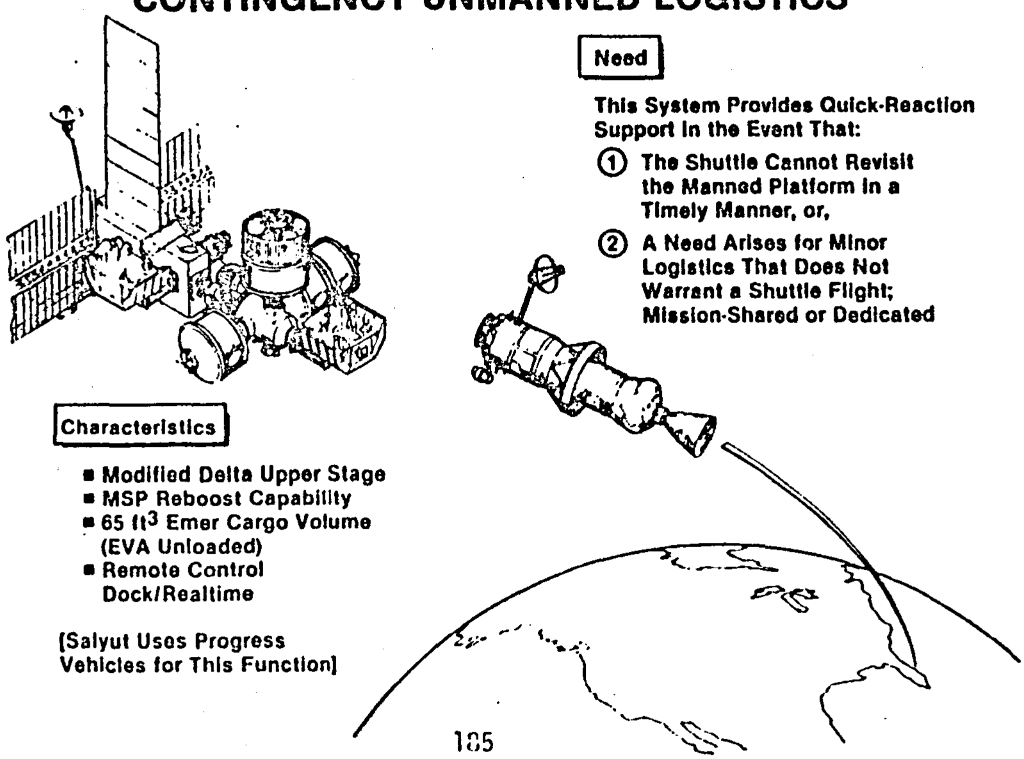
There are numerous situations envisioned for the Manned Platform wherein the Shuttle may not fulfill a logistics or contingency requirement. The Shuttle itself may be experiencing some problems which call for it to remain grounded pending resolution. This could, under unusual, but foreseeable, circumstances, apply to all Shuttles. In this event, situations may arise wherein support of the Manned Platform is in jeopardy and some alternate visit capability would be required, to provide supplies or reboost propellant. Also, there may be occasions where some logistics are required by the Platform, but the investment involved does not warrant a Shuttle flight, shared with another mission or not. Here again, some low-cost logistics system is warranted.

Figure 4.2.3.3-12 illustrates a concept based on the low-cost, quick reaction Delta vehicle, which could deliver approximately 65 ft^3 of volume type cargo to the Platform.

Thus, it appears advised to provide, as the Russians do, some unmanned, relative low-cost system to fulfill contingency needs of the Platform. In the section on Recommended Concept Summary (Section 6), additional details of the vehicle desig proposed here are presented.

Figure 4.2.3.3-12

CONTINGENCY UNMANNED LOGISTICS



Need

This System Provides Quick-Reaction Support In the Event That:

1. The Shuttle Cannot Revisit the Manned Platform In a Timely Manner, or,
2. A Need Arises for Minor Logistics That Does Not Warrant a Shuttle Flight; Mission-Shared or Dedicated

Characteristics

- Modified Delta Upper Stage
- MSP Reboost Capability
- 65 ft^3 Emer Cargo Volume (EVA Unloaded)
- Remote Control Dock/Realtime

[Salyut Uses Progress Vehicles for This Function]

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4.3 OPERATIONS ANALYSIS

The success of the Orbiter and its payload programs depends on efficient ground operations. As this activity is developed for both Orbiter and Spacelab, it was assumed, for purposes of this study, that the MSP would be similar to Spacelab in prelaunch and post mission support. Thus, the Spacelab ground operations can be immediately evaluated as a first step in the evolutionary growth to the Manned Space Platform era. However, an entirely new dimension for KSC Operations will be in the area of sustaining logistics and is touched on briefly here.

In orbit, the free-flying Manned Space Platform will be involved in orbital rendezvous and berthing, addition and removal of modules and autonomous flight operations. The role of the crew will assume a new dimension in the continuing operation of a long-duration Space Station supporting a demanding payload program; therefore, crew safety techniques and orbital operations must be employed that are consistent with precedents and standards established on previous manned spaceflight programs. To ensure the early application and consideration of operational and crew safety factors, the operations analysis was conducted in conjunction with the development and selection of MSP configurations.

4.3.1 Prelaunch/Launch Operations

The ground operations phase of a manned space program encompasses many distinct tasks and operations including prelaunch preparations, checkout, launch and post landing turnaround. Figure 4.3.1-1 illustrates the launch loading arrangements for the activation and logistics of the Manned Space Platform.

SASP Manned Module Launch Processing Summary

Figure 4.3.1-2 summarizes the launch processing activities for the three SASP flights required to establish the manned module operational configuration on-orbit.

The first flight will follow a standard vertical processing flow due to the hazardous reboost module (hydrazine propellant). Payload on-line operations are compatible with Orbiter assessed turnaround timelines.

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Figure 4.3.1-1

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INITIAL OPERATIONAL LAUNCH SEQUENCE

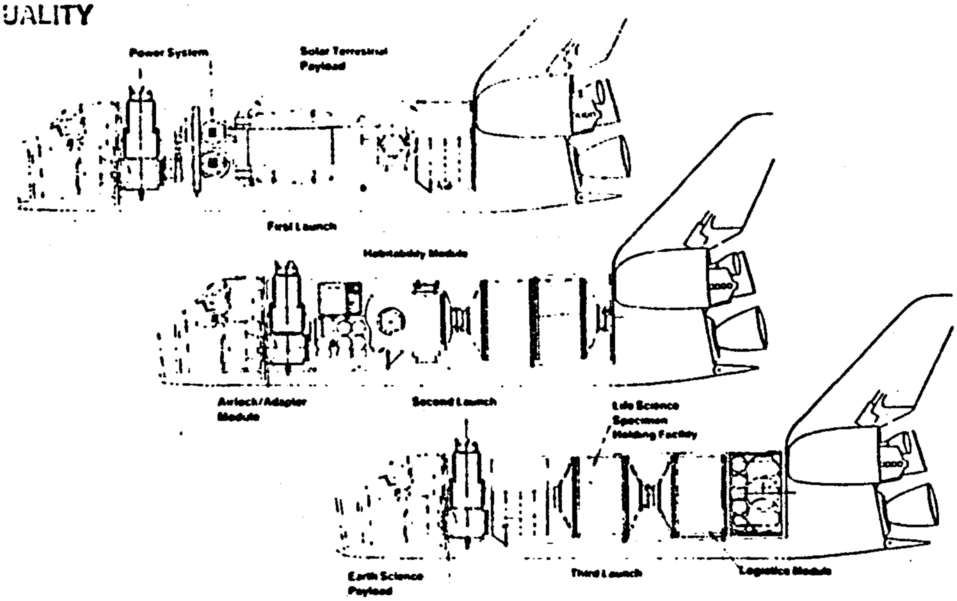

Figure 4.3.1-2

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MANNED MODULE LAUNCH PROCESSING SUMMARY

First Flight

- **Standard Vertical Processing Flow Due to Hazardous Reboost Module**
- **Compatible with On-Line Turnaround Timeline**
- **No Special Payload Operations**

Second Flight

- **Standard Horizontal Processing Flow**
- **Expendables Loaded in O&C Building**
- **Compatible with On-Line Turnaround Timeline**

Third Flight

- **Modified Horizontal Processing Flow (Life Science Payload)**
- **Expendables Loaded in O&C Building**
- **Cargo Bay Doors Opened on Pad for Live Specimen Installation**
- **Turnaround Timeline Extended 10 Hours**

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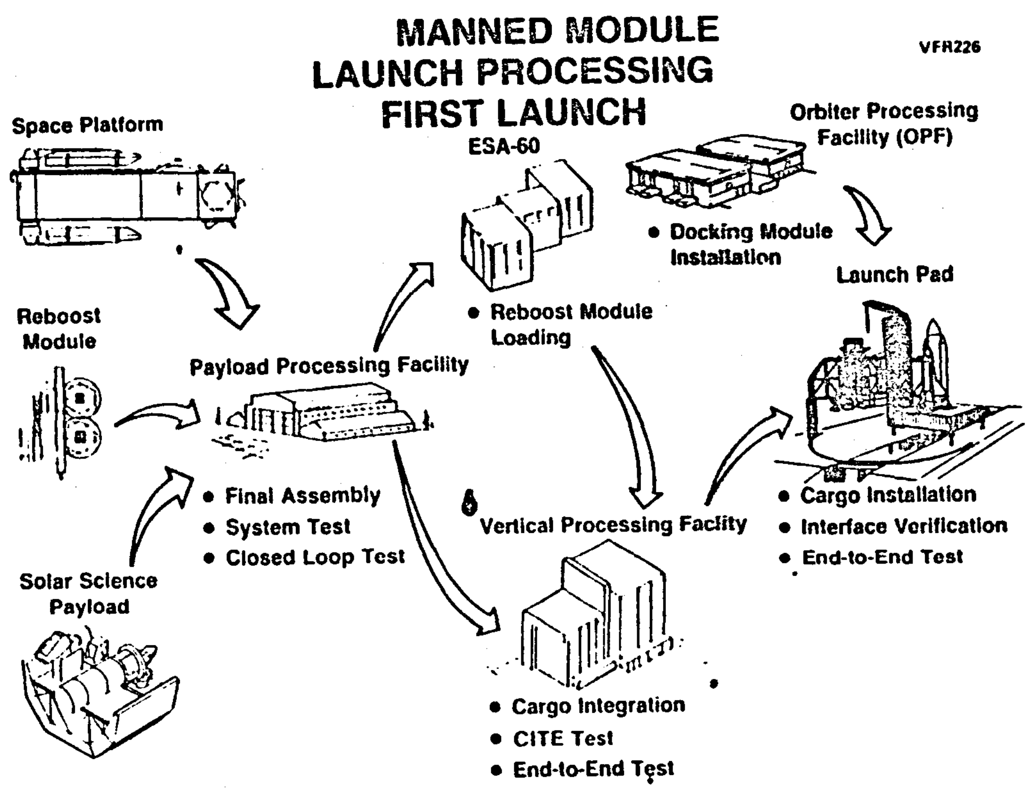
The second flight will follow a standard horizontal processing flow with expendables (oxygen, nitrogen, water and food) being loaded in the O&C building. All payload activities are compatible with turnaround timelines.

A modified horizontal flow is recommended for the third flight. The modification requires the payload bay doors be opened at the pad for live specimen installation in the life science facility. This adds 10 hours to the horizontal turnaround timeline.

The three payload elements (Space Platform, reboost module and solar science payload) will undergo final assembly and system test in appropriate payload processing facilities at the launch site (see Figure 4.3.1-3). A Space Platform closed loop test will be performed via the ground control center communications systems. The reboost module will have propellant loaded in a hazardous servicing area (i.e., ESA-60). Cargo integration and interface verification, via CITE, will be performed in the Vertical Processing Facility. The docking

Figure 4.3.1-3



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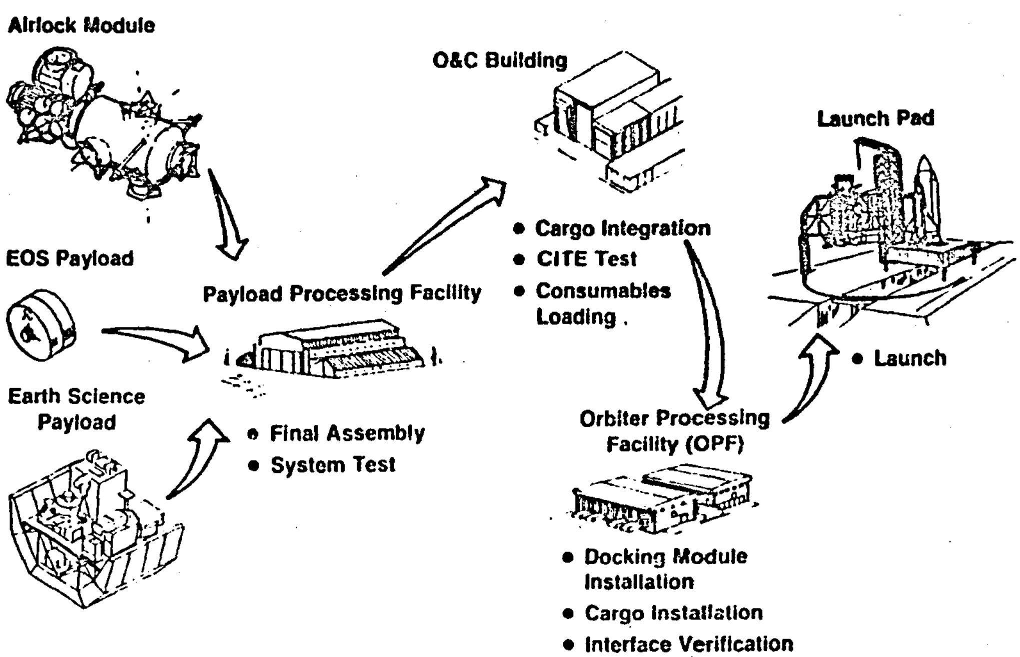
module would go directly to the Orbiter Processing Facility for installation in the Orbiter (assumes the module was utilized on previous unmanned Space Platforms). The cargo will be transported to the pad in a vertical position and installed in the Orbiter via the Rotating Service Structure.

For the second launch, the three payloads (airlock module, EOS payload and earth science payload) will undergo final assembly and system test in appropriate launch site payload processing facilities in a similar manner as the first flight payloads (see Figure 4.3.1-4). Since all payload elements are non-hazardous, cargo integration and interface verification will be accomplished in a horizontal mode in the Operations and Checkout (O&C) building. Airlock module consumables items will be loaded onboard as part of final operations. The cargo will be horizontally transported to the Orbiter Processing Facility and installed in the Orbiter cargo bay. There are no payload operations performed at the launch pad on this flight.

Figure 4.3.1-4

MANNED MODULE LAUNCH PROCESSING SECOND LAUNCH

VFR225



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For the third launch (see Figure 4.3.1-5), the logistics module and life science facility payloads will follow a horizontal launch processing flow similar to the second launch. The only difference will be live specimen installations for the life science facility at the launch pad. This will require opening the Orbiter cargo bay at the pad, since there is no direct access capability from the mid-deck to life science facility.

Figure 4.3.1-5

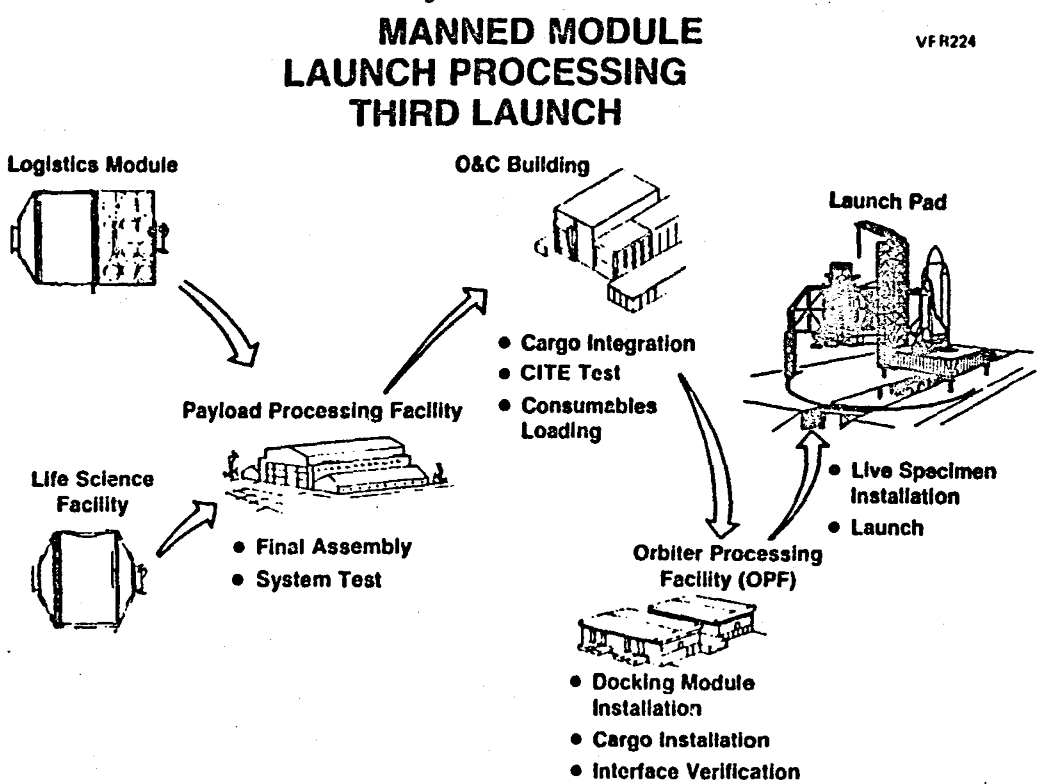
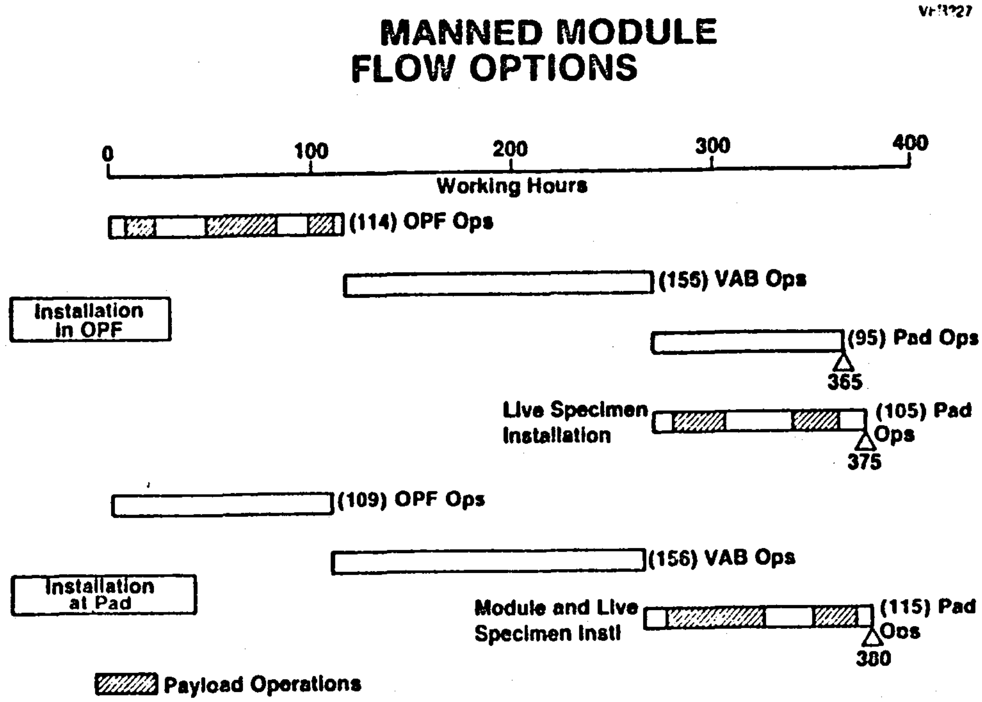


Figure 4.3.1-6 presents the various manned module ground flow option on-line timelines applicable for the first three flights. All timelines were based on the Shuttle assessed timelines in STAR 020.

The flows for payload "Installation in the OPF" would apply to Flights 2 and 3. Flight 2 would follow the 365-hour flow with all payload operations performed in the OPF. The Flight 3 flow is similar but adds 10 hours series flow time at the launch pad for live specimen installation (375-hour total flow).

Figure 4.3.1-6



Flight 1 would follow the payload "Installation at the Pad" flow with a 380-hour timeline. All payload on-line operations would be accomplished at the pad due to the hazardous reboost module. This flow option was also investigated for Flight 3 (live specimen installation), but resulted in a 5-hour longer timeline.

The major role of KSC in the long term logistics support of the Manned Space Platform is outlined briefly on Figure 4.3.1-7. Involved in such activities are extensive planning, storage, checkout refurbishment and consumables handling.

At least two ground operations tasks have a direct influence on the vehicle configuration. These are the internal access requirements after installation in the Orbiter cargo bay and the checkout/loading interface umbilicals. A cursory investigation of the internal access has been made; however, the umbilical locations are the subject of a preliminary design effort.

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Figure 4.3.1-7

KSC ROLE IN LOGISTICS

VFR272

- **Manned Platform Logistics Management**
  - Requirements Analysis
  - Planning and Scheduling
  - Facility Utilization
  - Training
  - Operations Control
- **Logistics Integration Operations**
  - Manned Module Support
  - Space Platform Support
  - Interior Payload Modules
  - Exterior Payload Modules
  - Large Structure Build Up
  - OTV Basing/Resupply
  - Spacecraft Servicing
  - Subsatellite Servicing
- **180 Day Logistics Module Turnaround (Typical)**
  - Unload
  - Refurbish
  - Load Internal/Externally Stored Consummables for Manned Modules and Space Platform
  - Load Payload Resupplies
  - Load New Payloads
  - Load On-Orbit Operations Aids
- **Training for On-Orbit Logistics and Related Operations**

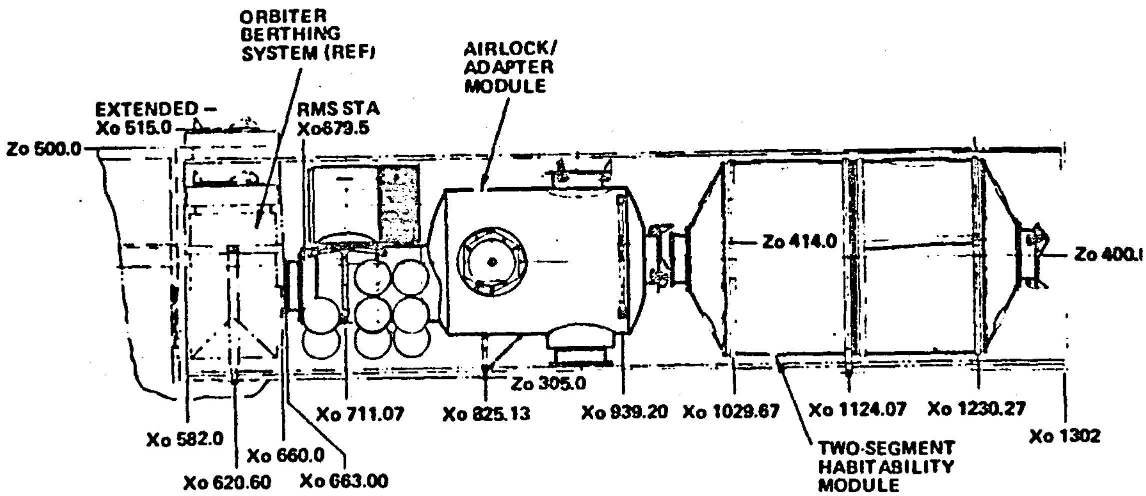
The MSP vehicle has four individual elements to be considered: the airlock/adapter, habitability/payload module, logistics module and payload modules. The logistics module should not require late access as it is relatively inert with regard to internal subsystems. Access to the other modules may be required during the prelaunch phase.

The basic MSP airlock/adapter and habitat are positioned in the cargo bay as shown in Figure 4.3.1-8. The two modules are not attached and the adapter is not attached to the Orbiter berthing system. As a result, direct access to the habitat is not possible in either the Orbiter Processing Facility (OPF) or at the launch pad. Indirect access to the habitability modules is possible in the horizontal or vertical position through the adapter berthing port located on the +Z axis, through the aft port and into the habitat. Since neither of these modules require loading of live specimens, it is suggested that all internal access operations be completed prior to MSP/Orbiter integration.

Size and location of payload modules indicate access will be possible in both orientations of the Orbiter including the launch pad.

Figure 4.3.1-8

CARGO BAY ARRANGEMENT



Early platform launch options were investigated for two on-orbit cases: (1) Power System on-orbit and (2) no Power System on-orbit. A summary of these options is outlined in Figure 4.3.1-9. In addition, the favored MSP configuration was derived from a series of operational considerations shown in Figure 4.3.1-10.

4.3.2 On-Orbit Operations

4.3.2.1 Requirements

The major MSP on-orbit operational requirements are shown in Table 4.3.2.1-1. These requirements must be satisfied for all MSP configurations.

4.3.2.2 MSP Operational Methods

The primary requirement of any operational method is to access all payload attach points on any cluster arrangement. This is true for initial attachment, payload removal and/or exchange and for experiment maintenance. Since the Orbiter is limited to a single rendezvous/berthing operation, it requires that all MSP elements be accessible from a single position. However, as the MSP

Figure 4.3.1-9

EARLY PLATFORM LOAD-PER-LAUNCH OPTIONS

VFK500N

	Power System on Orbit	No Power System on Orbit
Shuttle-Tended Platform	Launch ① Regular Adapter/Airlock, Logistics Rack and 2-Segment Spacelab	Launch ① Short Adapter/Airlock, Short Power System and 2-Segment Spacelab
	Launch ① Regular Adapter/Airlock and 3-Segment Spacelab	Launch ① Regular Airlock/Adapter and 3-Segment Spacelab [Power System Goes in ET Rumble Seat]
Manned Free-Flying Platform	Launch ② Logistics Rack and Reboost Module	Launch ① Regular Adapter/Airlock, Reboost Module and 12.5 kW Power System
	Launch ① Regular Adapter/Airlock and 3-Segment Spacelab [Regular Adapter/Airlock and Payload Berth Beam in ET Rumble Seat] Launch ② 3-Segment Spacelab and Logistics Rack	Launch ② 3-Segment Spacelab, Logistics Rack Launch ③ 3-Segment Spacelab, Adapter Airlock and Payload Berth Beam
	Launch ① One 2-Segment Spacelab, Regular Airlock Adapter and Logistics Rack Launch ② Two 2-Segment Spacelabs	Launch ① Regular Adapter/Airlock, Reboost Module, and 12.5 kW Power System Launch ② Two 2-Segment Spacelabs and Logistics Rack

Figure 4.3.1-10

OPERATIONAL CONSIDERATIONS IN CONFIGURATION DEVELOPMENT

- **Activation (Assembly of):**
  - Power System + Adapter-Access Module } Tended Free Flyer Only
  - Power System + Adapter-Access Module + Manned Module I } Tended Free Flyer Only
  - Power System + Adapter-Access Module + Manned Module I + Logistics Module
- **Capability Expansion (Add):**
  - Manned Module II, III
  - Dual Adapter-Access Module
  - Experiment Module(s)
  - Exterior Payload Support Beam
- **Payload Addition/Removal/Support**

  Interior Payloads

  Exterior Payloads
  - On Adapter Access Module
  - On Exterior Payload Support Beam
- **Platform Resupply (Exchange)**

  Logistics Module

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Table 4.3.2.1-1

MSP ON-ORBIT OPERATIONAL REQUIREMENTS

- MSP ELEMENTS TO BE REMOVABLE FROM CARGO BAY USING RMS.
- MSP INITIAL HABITABLE MODULES TO BE AUTOMATICALLY VERIFIED BEFORE MANNING.
- MSP TO BE DESIGNED CAPABLE OF ON-ORBIT CLUSTER RECONFIGURATION.
- PAYLOAD CARRIERS AND/OR MODULES TO BE INSTALLED, REMOVED OR EXCHANGED USING SINGLE RMS.
- BERTHING PROVISIONS TO BE INCORPORATED TO PLACE ALL PAYLOADS WITHIN RMS CAPABILITY.
- ALL PAYLOAD CARRIERS TO BE EQUIPPED WITH UNIVERSAL BERTHING/UMBILICAL MECHANISM AND STANDARD RMS GRAPPLE FITTING.
- PLATFORM ORBIT-KEEPING FUNCTION TO BE PROVIDED BY POWER SYSTEM AND/OR ORBITER AS REQUIRED.
- PERIODIC SERVICING AND MAINTENANCE TO BE PERFORMED BY EVA CREWMAN WITH ASSISTANCE OF RMS.
- MAINTAIN A POSITIVE ATTACHMENT BETWEEN ORBITER AND MSP DURING ASSEMBLY AND/OR SERVICING OPERATIONS.

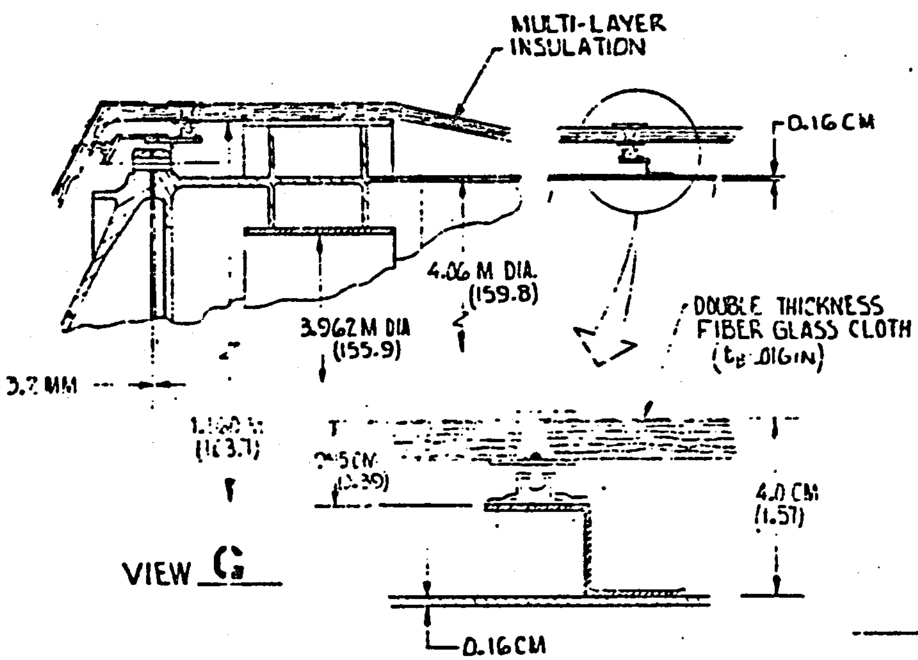
grows in complexity, multiple berthing provisions will be required at discrete locations. The current favored operational method is using a single RMS with rotation capability incorporated in the Orbiter berthing system interface mechanism. The first order Space Platform rotating berthing mechanism, shown on various figures, is defined in Document MDC G9246, "Conceptual Design Study of a Science & Applications Space Platform (SASP)," dated October 1980.

A standard handling method will be required to remove/replace payloads in the Orbiter cargo bay and attach/remove payloads from the MSP. The RMS end effector and grapple fixture were selected as the standard system. A grapple fixture, as defined in the Space Shuttle System Payload Accommodations Handbook, JSC 07700, will be required on each module and/or pallet.

The payload/MSP berthing attach points will not be visible to the eye of the RMS operator attempting to position the payload. Therefore, some type of visual assistance will be required. The current favored concept is use of TV cameras mounted at each berthing port incorporated in the design of the active interface mechanism.

The method incorporated for placing the first order Space Platform on-orbit is shown in Figure 4.3.2.2-1, As shown, the Power System is berthed at Orbiter Station Xo 550 by means of a rotating berthing adapter. This adapter interfaces with the Orbiter berthing system and provides rotational capabilities at both interfaces. Each payload berthing port can be accessed by the RMS with the SP in this location. Access to the (+Y) port is made possible with rotation about Station Xo 550 and/or Station Xo 633.

Access to elements of the basic Manned Space Platform (MSP) is shown in Figure 4.3.2.2-2 (sheets 1, 2 and 3). The MSP is berthed to the Orbiter along the (X) axis and interfaces with the Orbiter berthing system at Station Xo 633. From this position, the RMS has access to the SP (-Y) axis payload and the (-Y) axis payloads berthed to the airlock/adapter module, plus access to the adapter +Z payload. Access to payloads mounted on the (+Y) axis of both SP and adapter require rotation about the interface at Orbiter Station Xo 633. The SP parking port on the +Z axis is not accessible by the RMS with payloads berthed to the adapter +Z port; therefore, a parking port is made available on the payload



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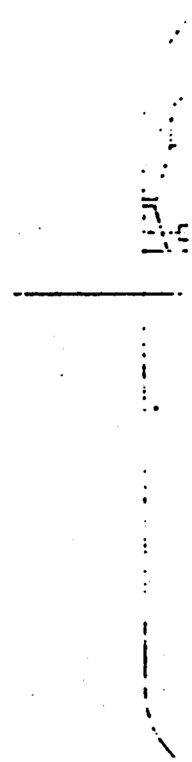

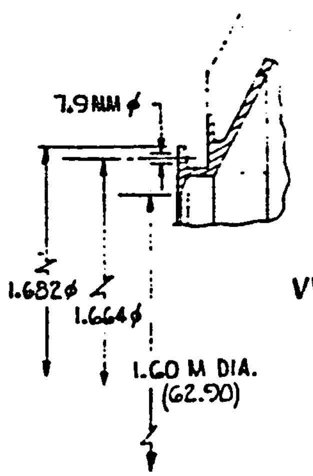

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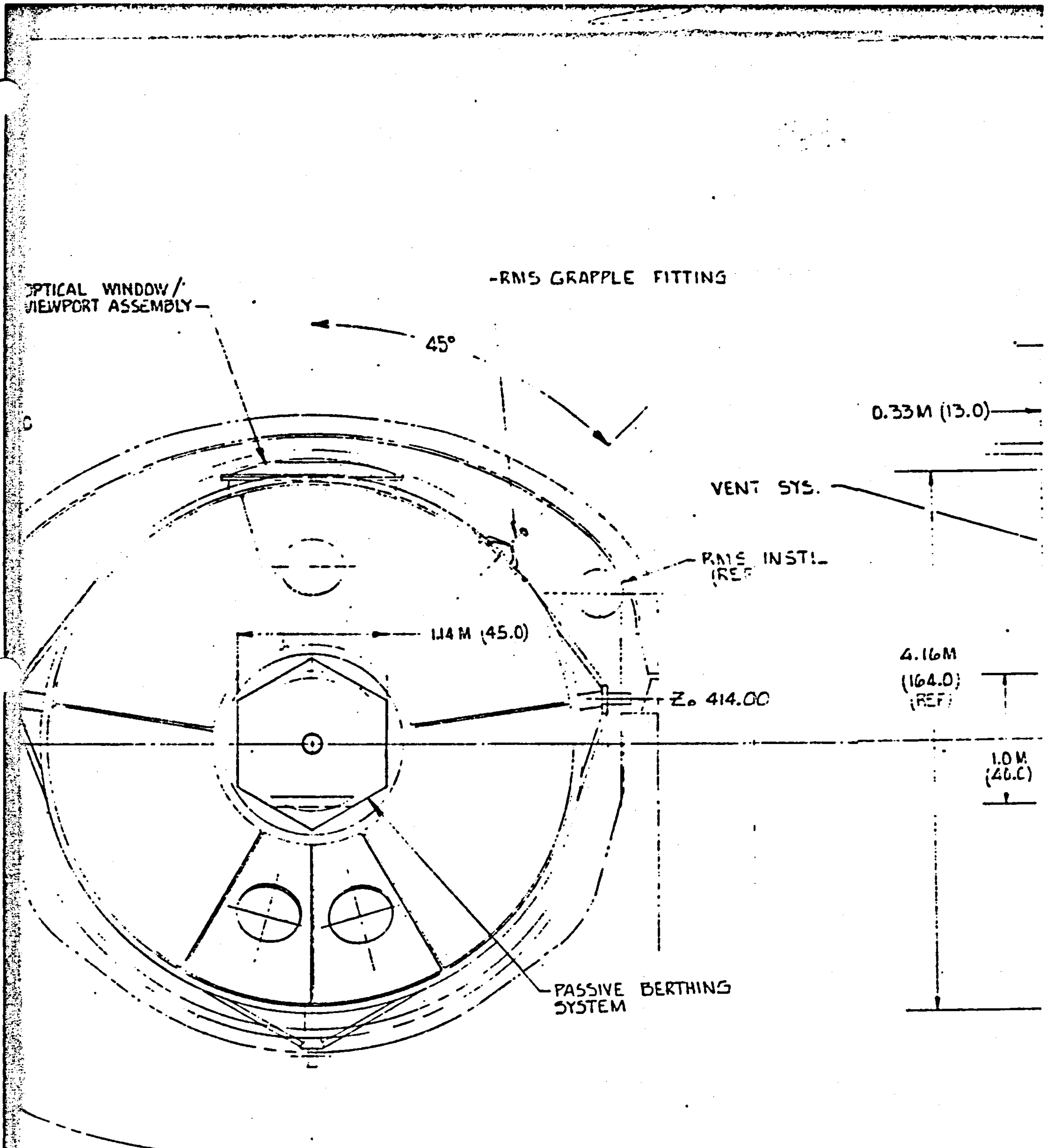

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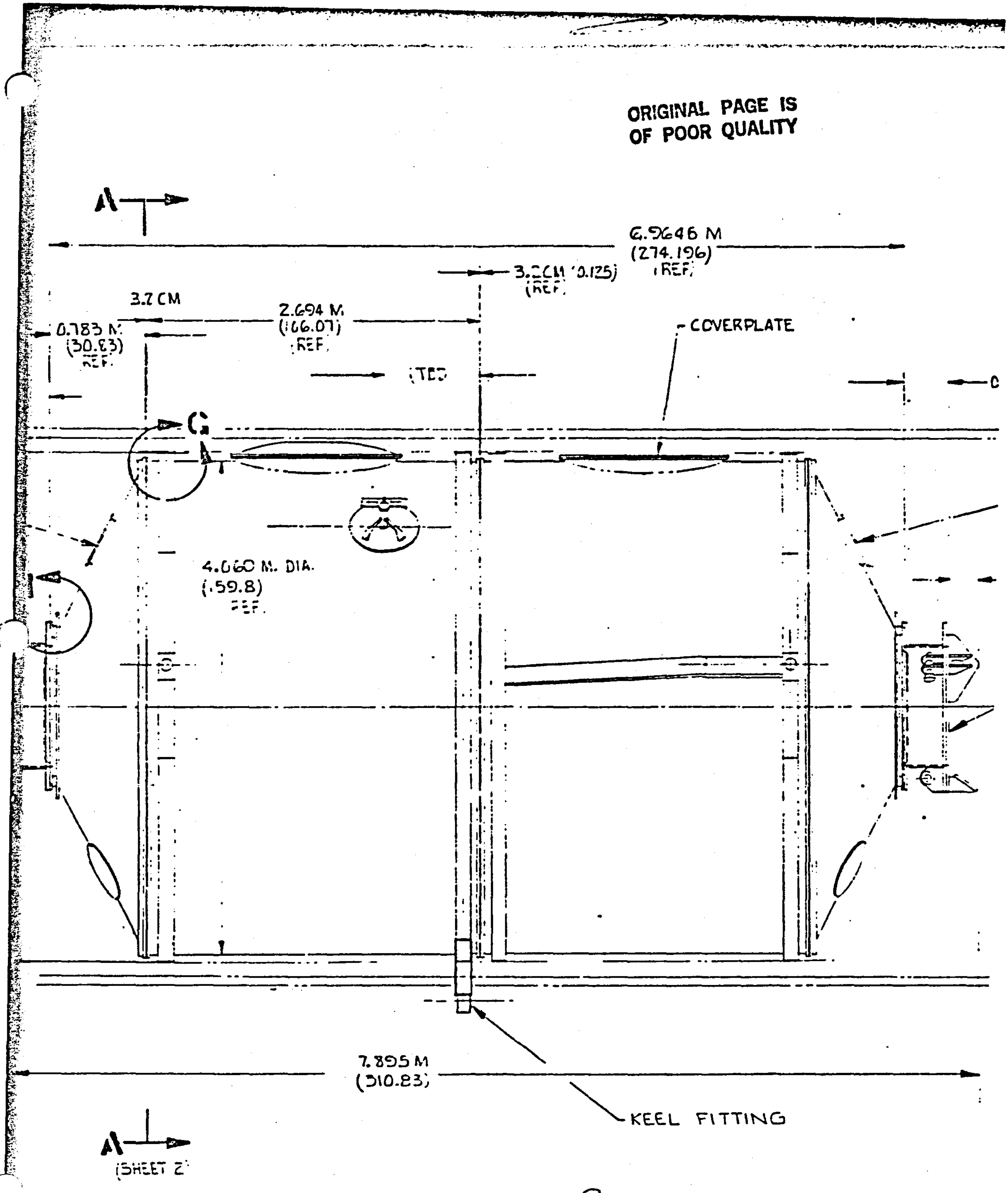

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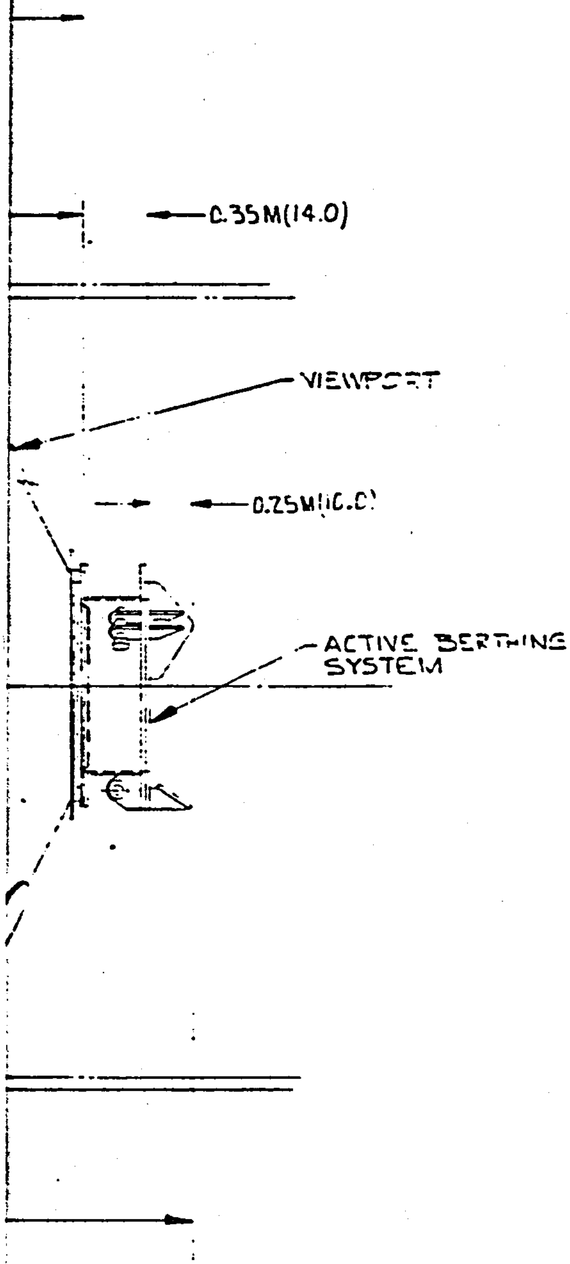

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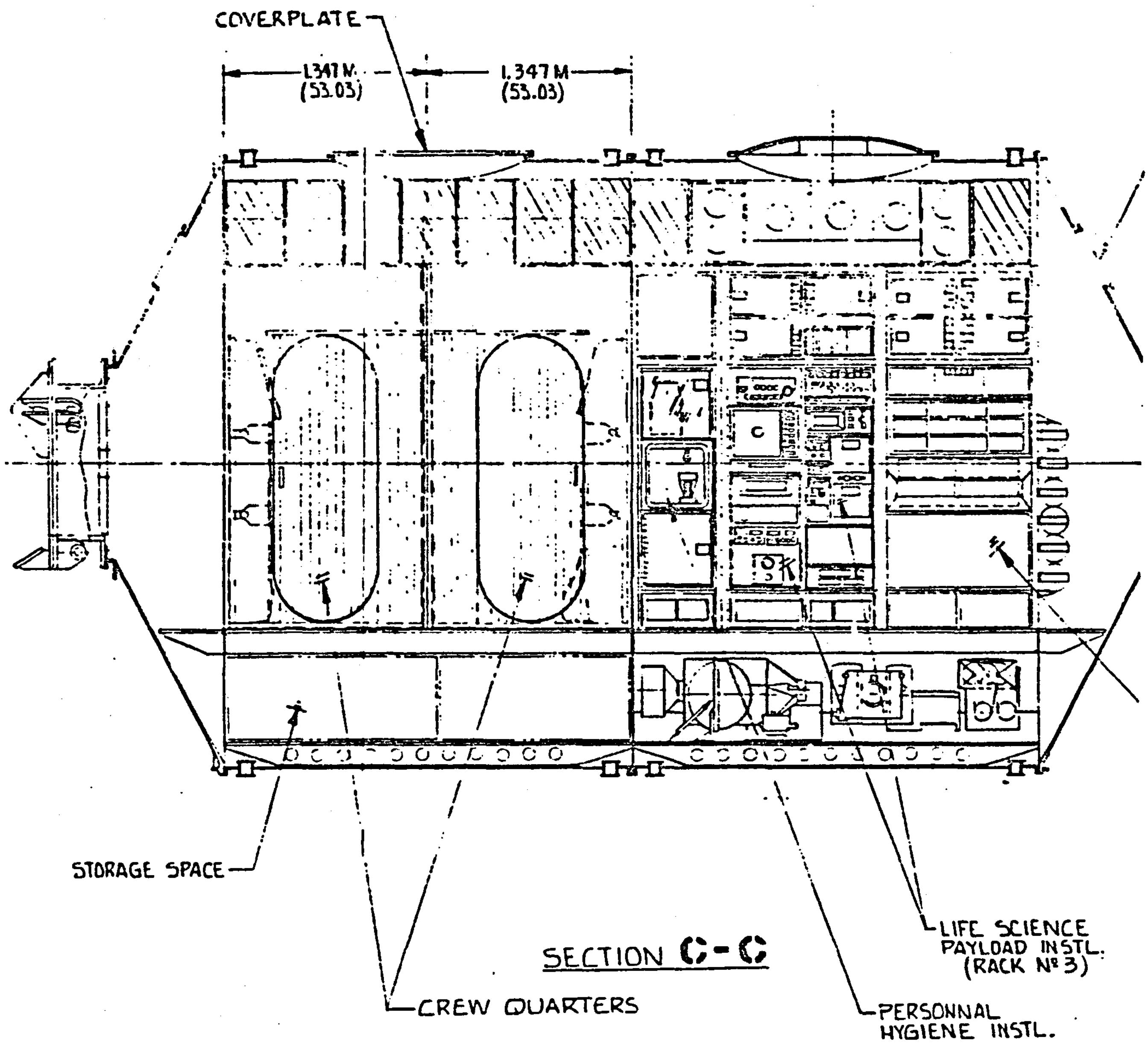

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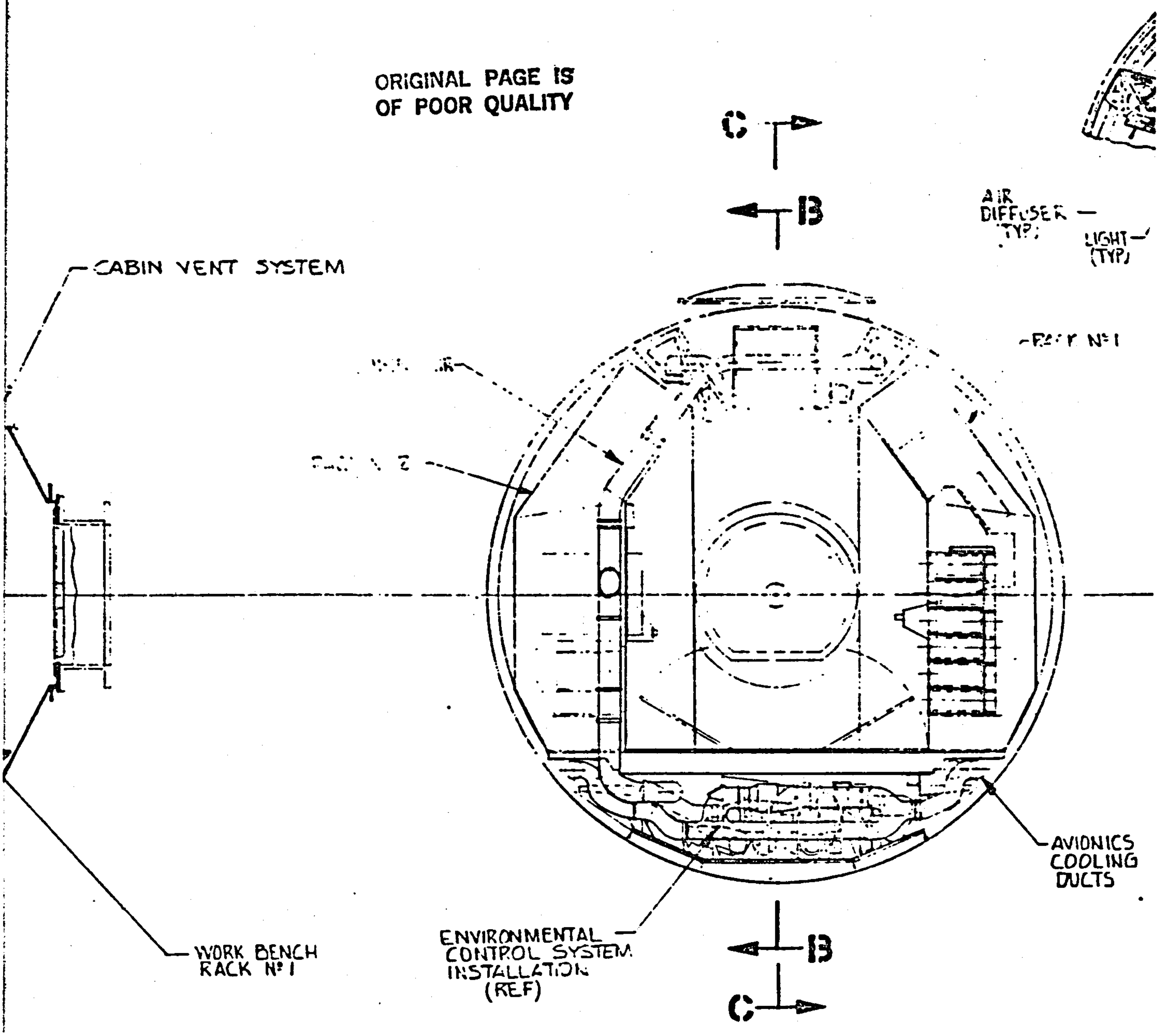

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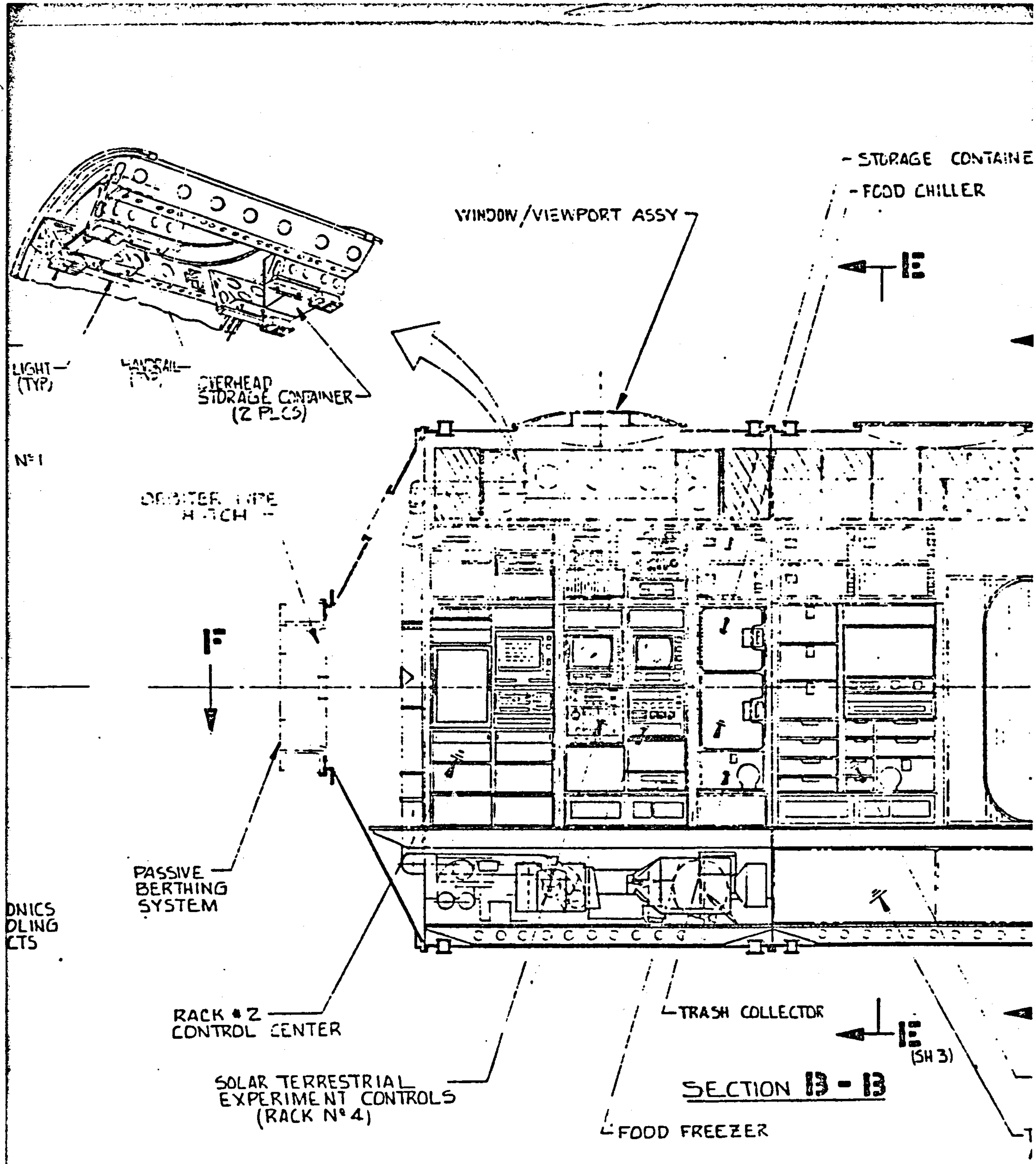

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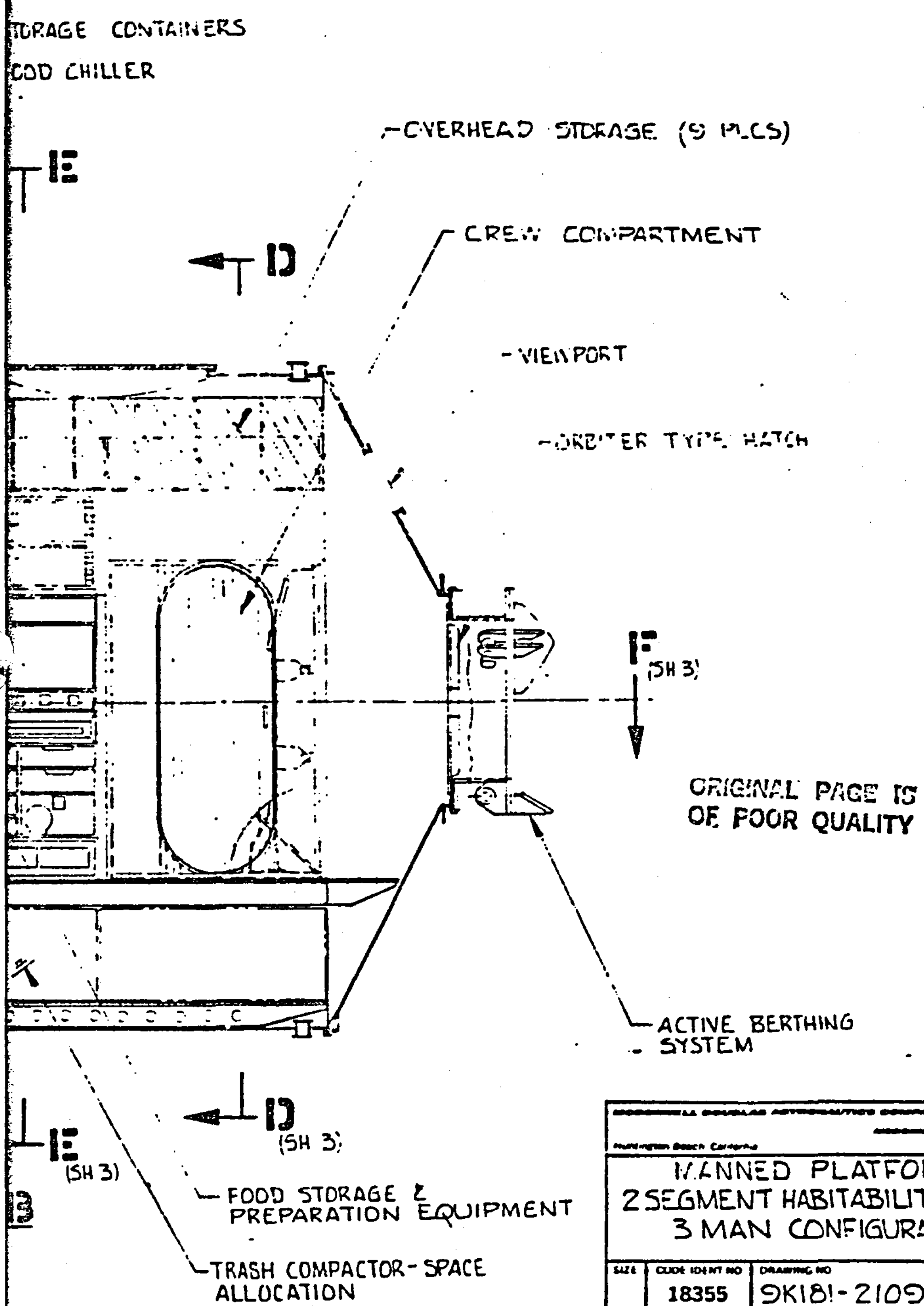

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MANNED PLATFORM
2 SEGMENT HABITABILITY MODULE
3 MAN CONFIGURATION

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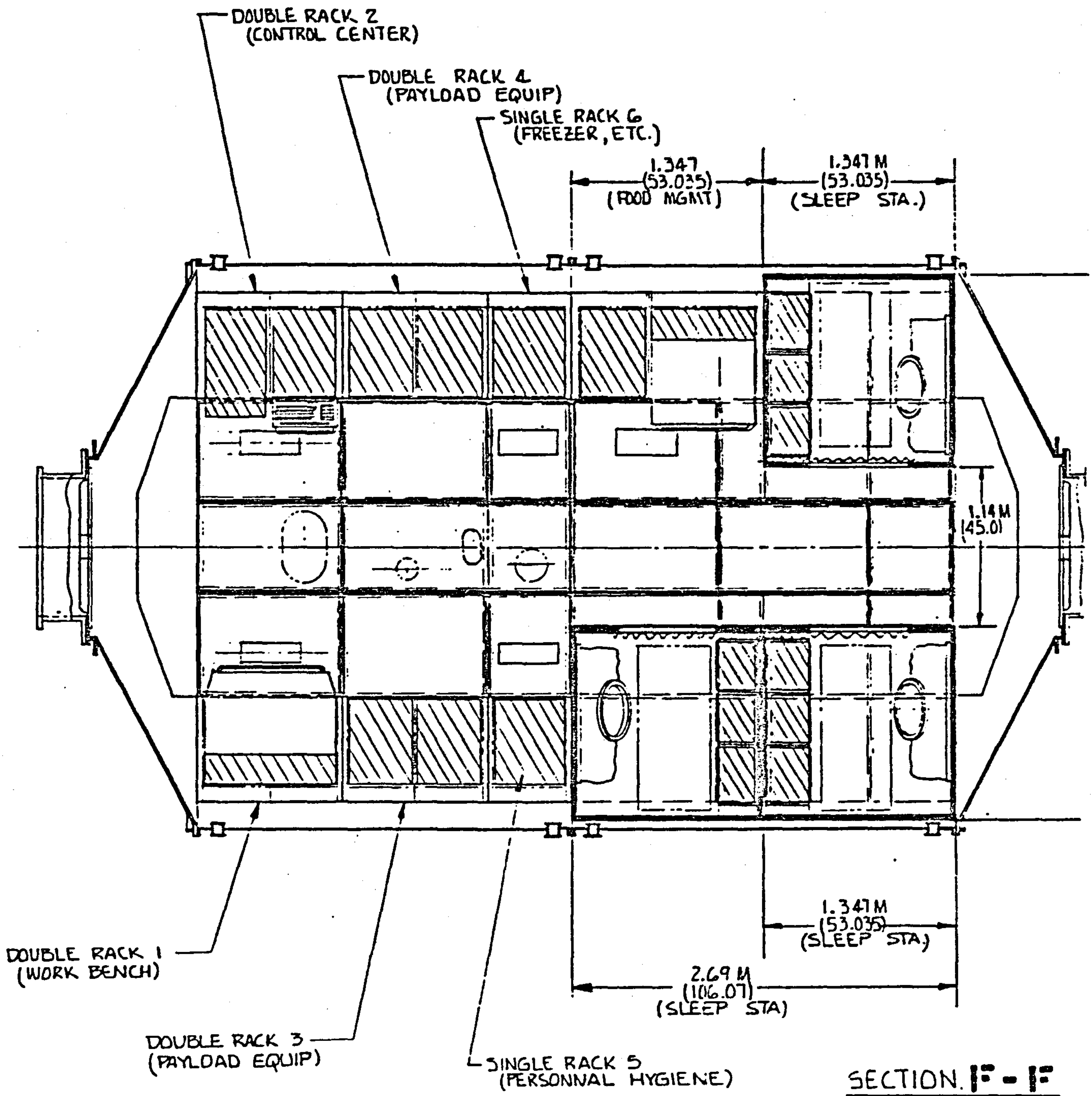

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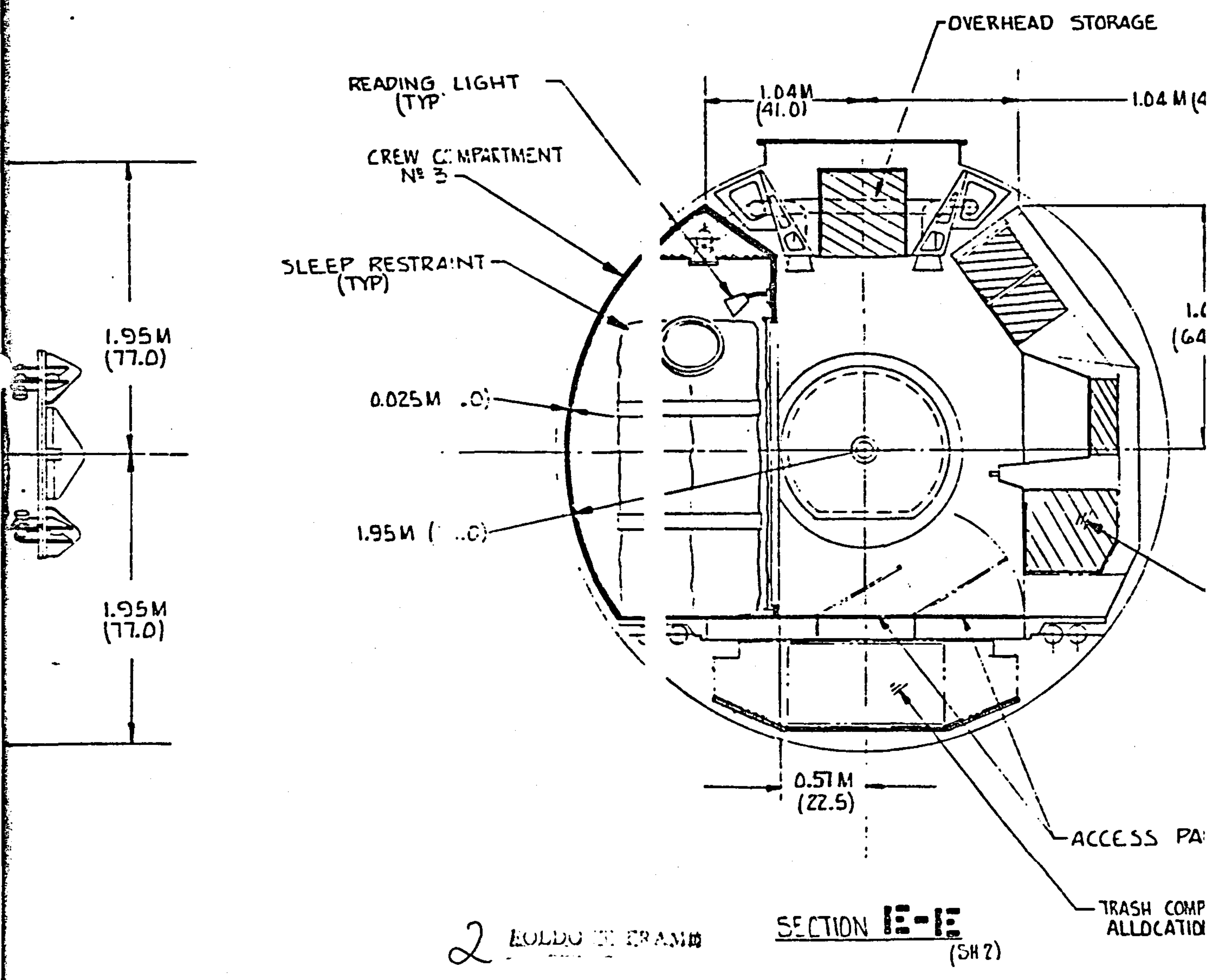

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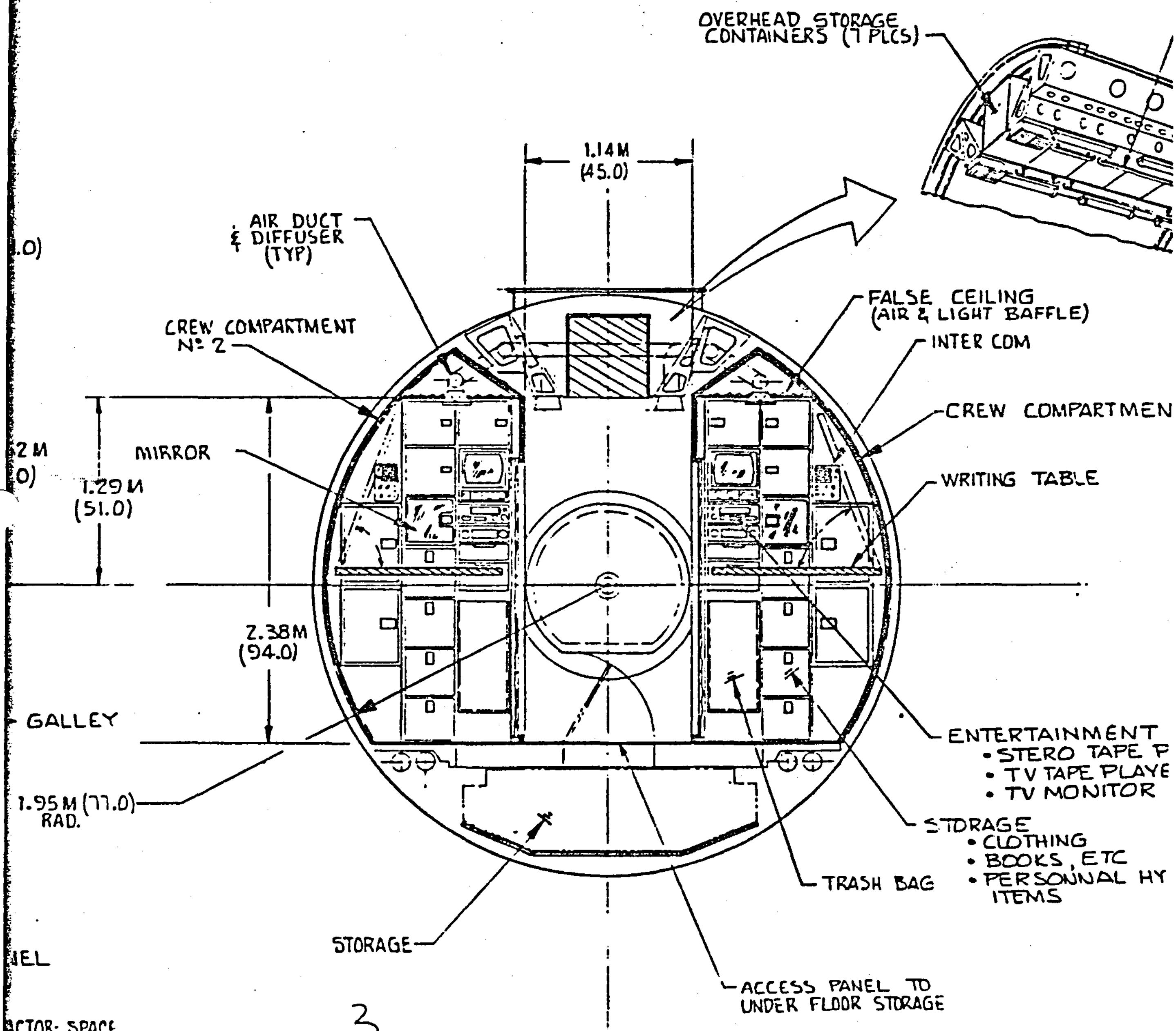

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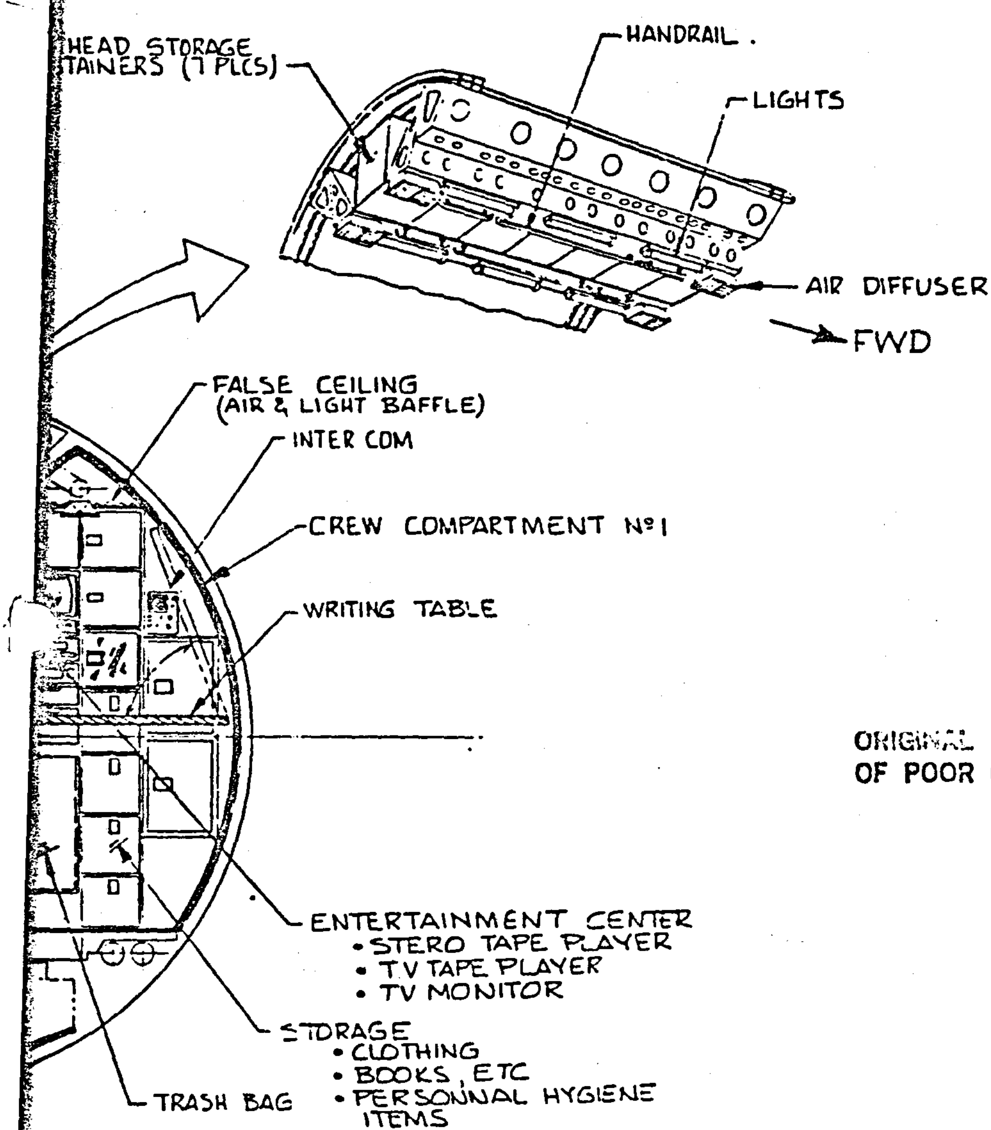

MANNED PLATFORM
2 SEGMENT HABITABILITY MODULE
3 MAN CONFIGURATION

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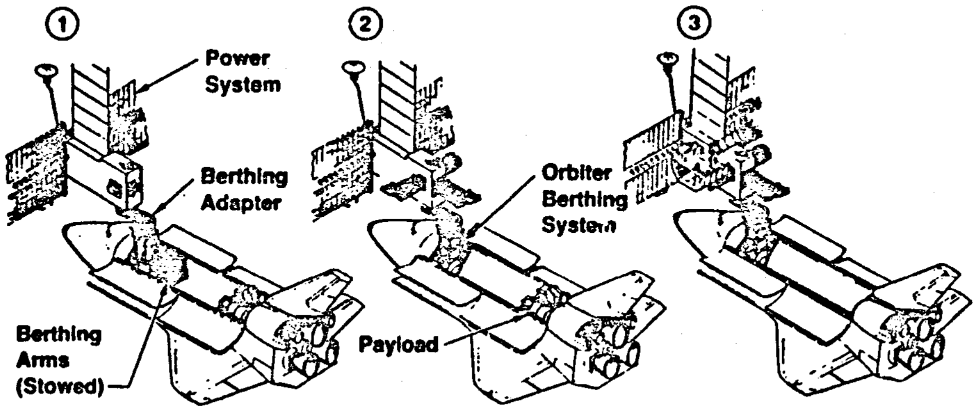
Figure 4.3.2.2-1

1ST ORDER SP DEPLOYMENT



- Deploy and Attach SASP Berthing Adapter To Orbiter Berthing System
- Remove Power System From Cargo Bay and Position on Adapter
- Deploy PS Components and Verify

- Remove Payload Berthing Arms and Install on ±Y and +X Axis of Power System

- Remove Solar Terrestrial Payload and Position On-Y Axis Berthing Arm
- Verify Systems and Place On-Orbit

support beam. The support beam is berthed to the adapter +X port with rotational features that enable it to be moved away from the cargo bay permitting access to items being deployed from the bay. Modules being replaced can be placed on the beam until space becomes available in the cargo bay and final exchange can be made.

Access to the SP reboost module or other elements in that vicinity, requires the SP/Orbiter be berthed as shown in Figure 4.3.2.2-3. Reberthing of the MSP will be necessary if crew transfer is required during any phase of this particular mission. It is anticipated that reberthing can be achieved with the RMS. If reberthing is not practical, incorporation of a second RMS, aft mounted in the Orbiter cargo bay or an onboard manipulator sized to reach SP components, are feasible alternatives.

Figure 4.3.2.2-3

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REBOOST MODULE REPLACEMENT

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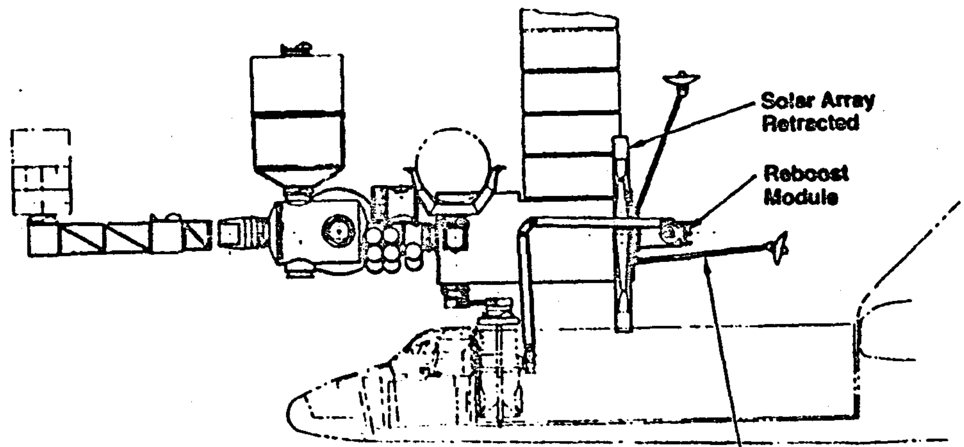

4.3.2.3 Basic MSP Orbital Operations

The basic MSP operational buildup shown in Figure 4.3.2.3-1 begins with the launch of the first order Space Platform and one palletized payload. Following system verification and activation, the SP is placed on-orbit. The second launch delivers the airlock/adapter and the habitability module. Following deployment and verification of the Orbiter berthing system, rendezvous with the SP is accomplished and the SP is berthed to the Orbiter. After interface verification, the RMS removes the SP (+X) payload arm and positions it on the SP parking port. The airlock/adapter is then removed from the cargo bay and berthed to the SP (+X) port. Following verification of interface, the SP is released from the Orbiter with the RMS and the SP berthing arm is stowed. The RMS then berths the airlock/adapter to the Orbiter. Checkout of the adapter subsystems, etc., can now be performed in a shirtsleeve environment. After checkout, the assembly is rotated to the (+Y) axis and the habitability module is positioned on the adapter (+Y) port. The cluster is then rotated to the X axis and the MSP is manned. Following all systems checkout, the cluster is placed on-orbit with a crew of three and supplies for 90 days plus 30-day contingency.

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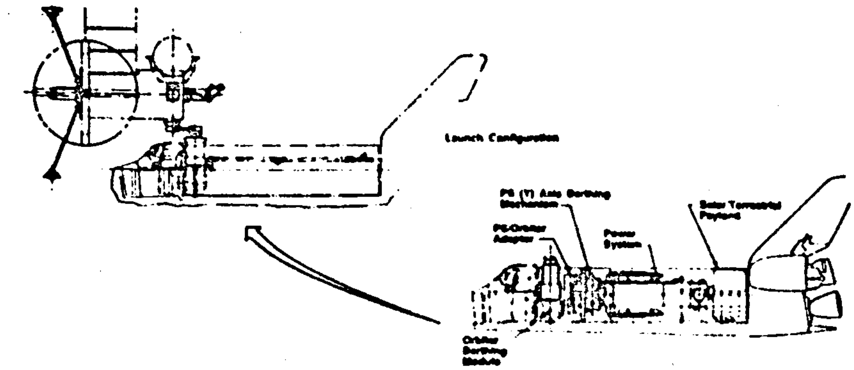
Figure 4.3.2.3-1

INITIAL OPERATIONAL LAUNCH SEQUENCE

FIRST LAUNCH



SECOND LAUNCH

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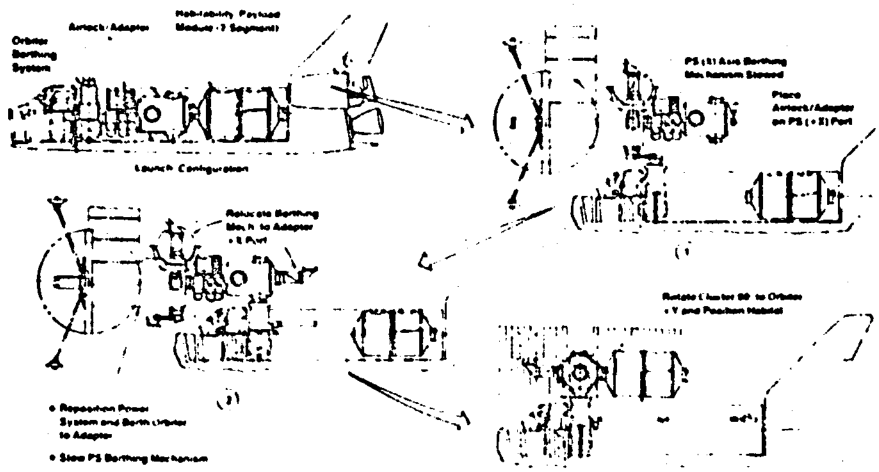

THIRD LAUNCH

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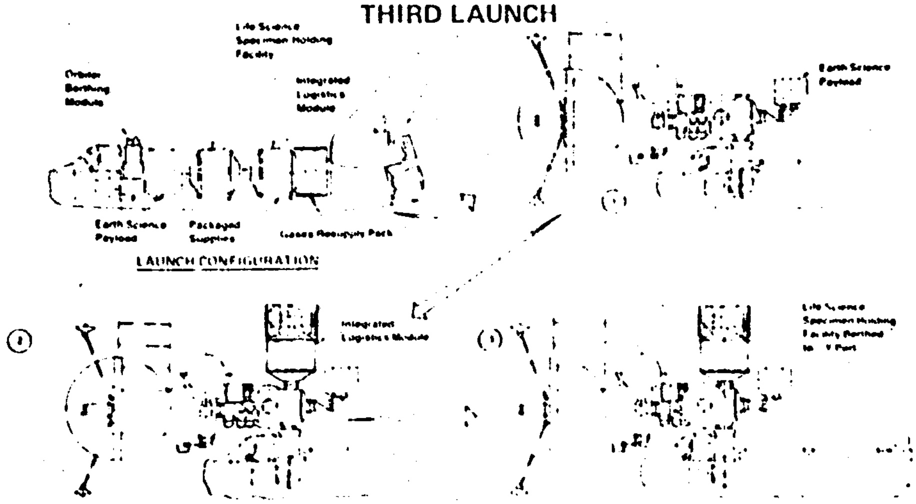

After 90 days maximum, the resupply launch delivers the logistics module, one element of the life science experiment, and the earth-looking payload. Following rendezvous, the RMS captures the MSP and performs operations to join the MSP/Orbiter. After verifying the interface crew transfer can be accomplished, using the RMS, the logistics module is removed from the cargo bay and placed on the adapter (+Z) port and the life science module is placed on the (-Y) port. No rotation is required to accomplish these berthings. In order to position the earth-looking payload, the RMS first removes the short payload beam from the SP parking port and places it on the adapter +X port. The payload pallet can then be removed from the cargo bay and positioned on the short beam. On a subsequent resupply flight the extended payload support beam is delivered and exchanged with the smaller first order arm. After the assembly sequences are complete, the crew will transfer between the MSP and Orbiter and begin the debriefing and information exchange between the returning crew and the replacement personnel. Provisions are provided in the basic concept to permit several days of such briefings. The Orbiter will remain attached to the MSP during this period.

Flight operations are based on a 90-day rotation of the flight crew; however, resupply cycle is based on a 180-day rotation. This permits full use of alternate flights for payload support. As a result, the fourth launch delivers the second portion of the life science experiment plus a material science payload, as well as exchange crew. Personal supplies and unprogrammed logistics are delivered in the Orbiter mid-deck.

Following delivery of the life science modules, earth, solar and material processing experiments, the MSP is a complete operating manned orbital facility.

4.3.2.4 MSP Growth

The basic concept provides a number of growth options leading to expanded facilities, crew size and operations. The basic design can provide for the support of satellite servicing and/or the assembly of large space antenna/structures. The crew-supported functions necessary to achieve these capabilities are inherent in the basic concept. Figure 4.3.2.4-1 illustrates two possible growth concepts for the basic radial clustered MSP and Figure 4.3.2.4-2

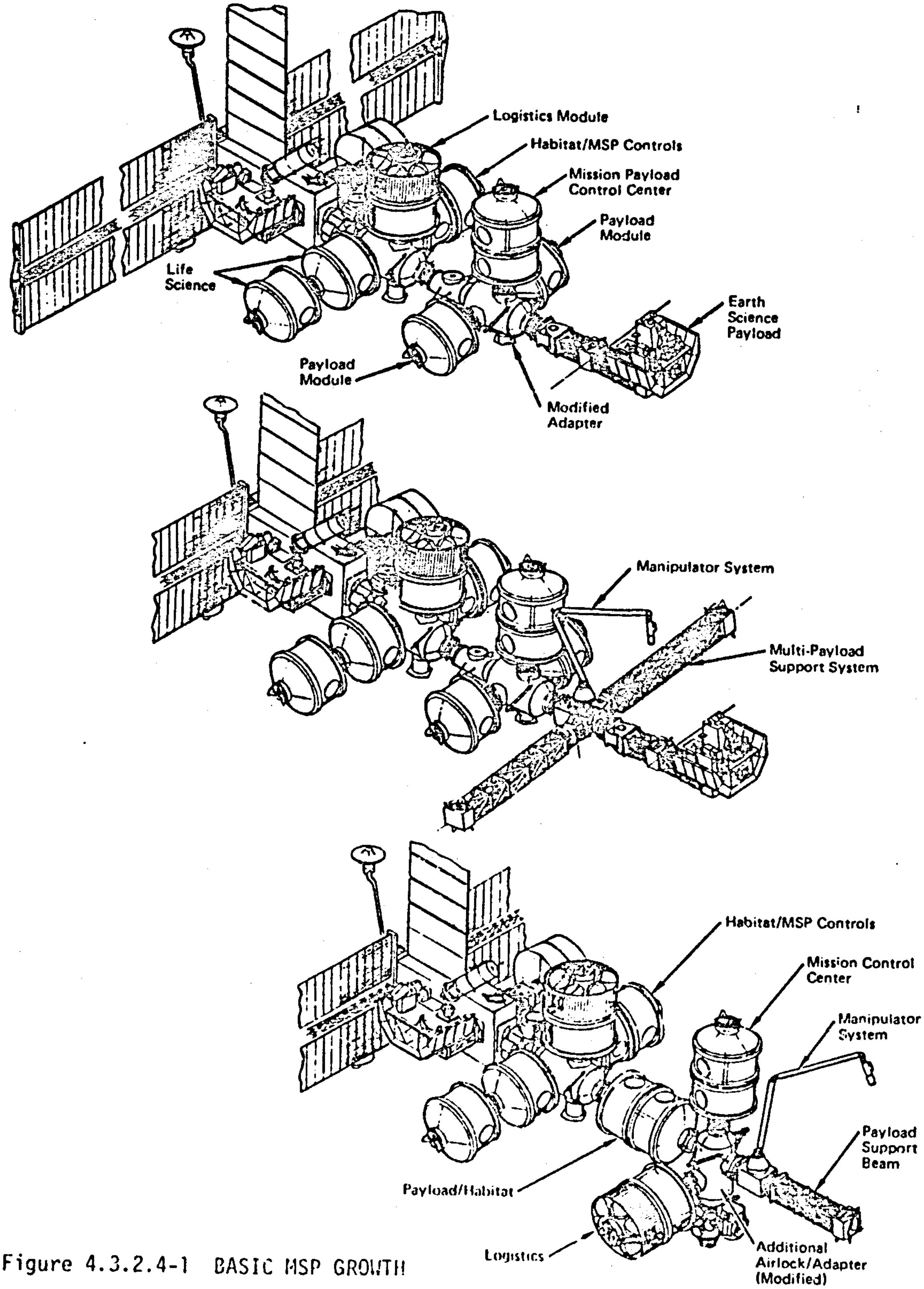

Figure 4.3.2.4-1 BASIC MSP GROWTH
OPTIONS

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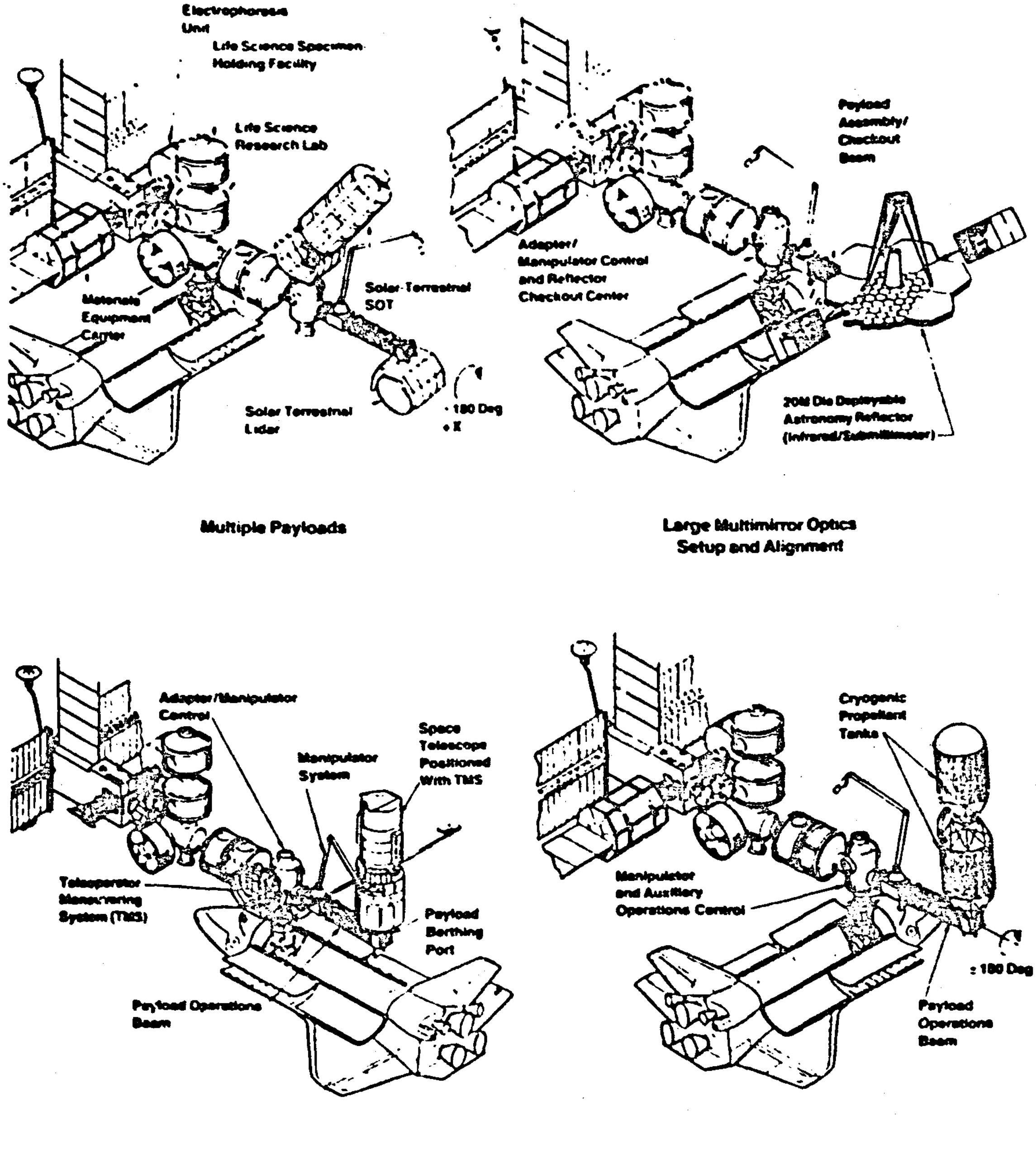
Figure 4.3.2.4-2

MANNED PLATFORM OPERATIONAL GROWTH OPTIONS



Multiple Payloads

Large Multimirror Optics Setup and Alignment

Servicing Retrievable Spacecraft

OTV Technology Testing

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illustrates the growth possibilities for the linear cluster arrangement. In all concepts evaluated during the study, multiple berthing provisions for the Orbiter were required to minimize MSP/cargo bay obstruction.

OTV operations on the Platform represent a very complex activity as spelled out in a previous section (Section 2.7.11), OTV Basing. Many details regarding the nature of such an activity and the impact on the Platform were descirbed in that section.

In order to highlight the unique operational considerations in prospect for OTV basing on the manned Platform, the following four figures are presented here to complement those given earlier in this report.

Figure 4.3.2.4-3 illusrates the overall configurations for OTV basing and Figure 4.3.2.4-4 the launch sequence envisioned. The various types of operations and facilities are given in Figure 4.3.2.4-5 and a comparison, for each subsystem, as to crew checkout in-orbit will vary from the classic methods used on the ground (Figure 4.3.2.4-6).

Figure 4.3.2.4-3
MANNED PLATFORM FOR OTV OPERATIONS

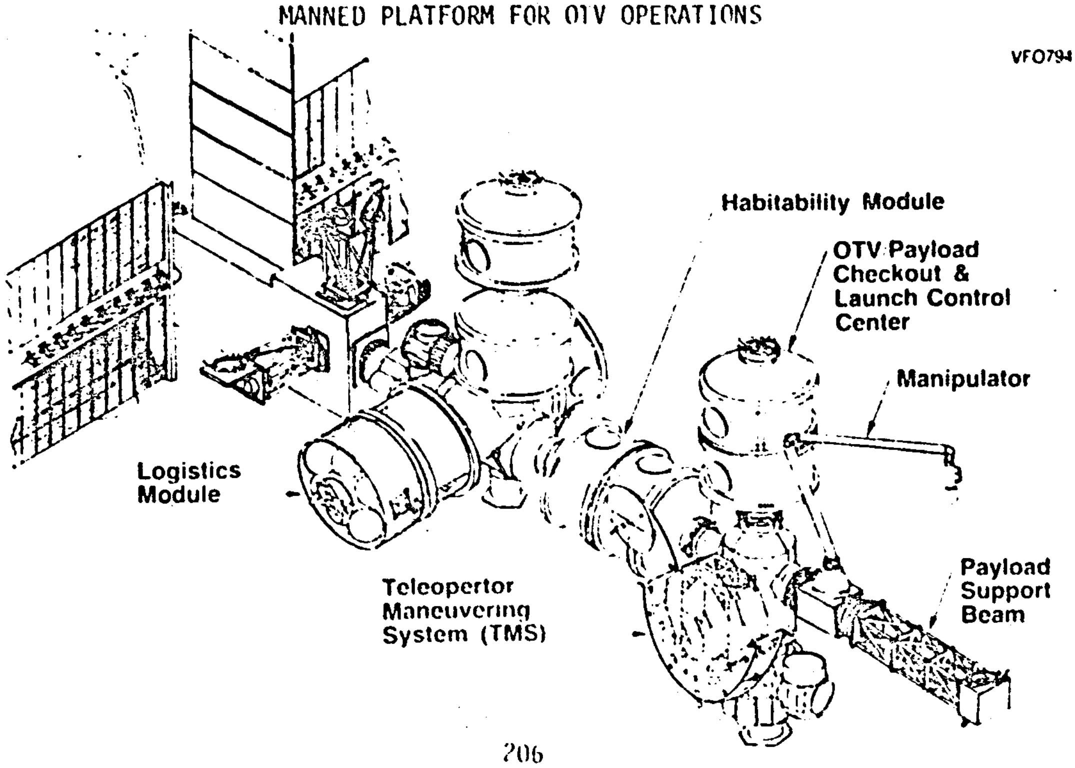

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Figure 4.3.2.4-4

OTV OPERATING SCENARIO (LAUNCH SEQUENCE)

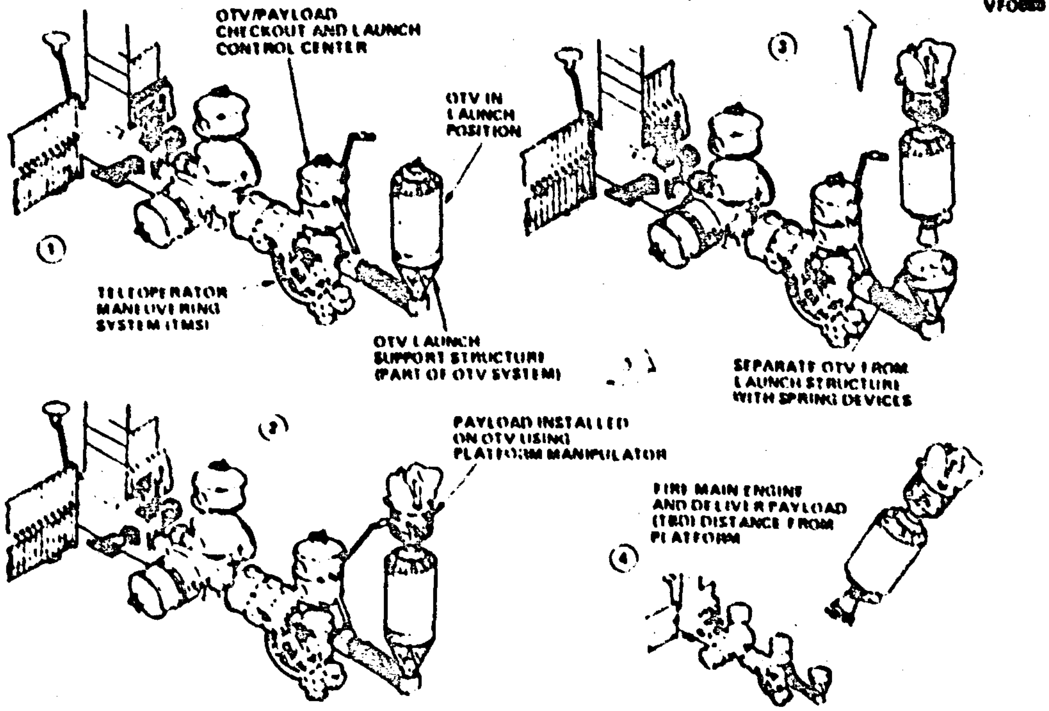

Figure 4.3.2.4-5

OTV/PLATFORM OPERATIONS AND FACILITIES

- Manipulation and Berthing of Large and or Multiple OTV Propellant Tanks and Payloads
- OTV (RE)Fueling
- Resupply Other Expendables (I.E., Gases, Batteries, Hydraulic Fluid)
- OTV Checkout — Maximize Self-Checking
- OTV Maintenance — Simple Functions Only

- Propellant Storage Transfer Tanks
- Propellant Transfer Equipment
- Pressurant Transfer Equipment
- Platform OTV Umbilical
- Checkout Console
- Checkout Support Equipment
- Control Center
- Remote Manipulator System for Payload Interchange

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Figure 4.3.2.4-6
OTV CHECKOUT ON PLATFORM

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Subsystems	How Different From Ground?
Propulsion • Leak Checks • Valve Functional Checks • Instrumentation Calibration	• Limited (or No) On-Line Replacement of Hardware
Thermal • Insulation • Heaters	• Multiple Firing (Use of Cryogenic Engines with Minimum C O
Mechanical • Engine Gimbaling • Berthing Mechanism — Separation • Payload OTV Separation and Berthing	• Limited Crew Size — Maximize Self-Checking and Computer C O • On-Orbit Updating of Controls Software
Electrical • Power Subsystem Checkout • Guidance and Navigation Subsystem • Telemetry and Comm System	• Limited Data Processing Capability • Limited Power Resources
Avionics • Data Management Subsystem • Computer C O	• Limited Capability For Cooling Electronics

4.4 MAINTENANCE, RELIABILITY, AND SAFETY ANALYSES

Past space missions have demonstrated that on-orbit maintenance capability can significantly contribute to achieving mission success. However, these missions have shown the need for increased emphasis on maintainable design of systems and equipment both internal and external of the manned Platform.

The high degree of reliability designed into Platform systems cannot alone insure mission success, since it is impossible to anticipate every failure which might occur. An on-orbit maintenance capability can provide a means of overcoming the effects of unanticipated failure or damage and can preserve the high inherent reliability of the systems and equipment.

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4.4.1 Maintenance Philosophy and Assumptions

The criteria presented here and to be included in the "Manned Space Platform Design Guidelines and Criteria" document (Appendix C), are based on the following assumptions, concerning maintenance philosophy, and mission objectives relative to development of an on-orbit maintenance capability.

A. On-Orbit maintenance will be performed on the manned modules and on retrieved and/or revisited vehicles.

B. The Manned Space Platform elements to be designed for ten-year mission with no maintenance.

C. Subsystem design is to provide for orbital maintenance.

D. Although planned maintenance will be minimized, scheduled on-orbit maintenance will be performed as a means of preserving system and equipment integrity through replacement of life-limited components, servicing and adjustment.

E. Unscheduled on-orbit maintenance will be performed to restore system and equipment operations and to restore failed or malfunctioning redundant items for which pre-planned maintenance support requirements have been established.

F. Where feasible, contingency on-orbit maintenance will be performed whenever unanticipated damage or failure occurs which could jeopardize mission success or safety of the crew.

G. The capability for module replacement for subsystem maintenance to be considered as an unscheduled major event resulting from an accident, not a failure.

H. Both EVA and IVA maintenance will be considered.

I. Manned Platform elements requiring EVA maintenance should be designed for two-man operation.

J. Whenever practical, experiment or support systems are to be designed such that on-orbit replacement can be made at the "black box" level.

K. On-orbit maintenance capability in the form of tools, spares, repair materials, maintenance equipment and procedures will be provided for support of planned and contingency maintenance.

L. Astronaut transports maintenance items from storage to worksite.

M. EVA astronaut will also transport tools/aids and establish personal work restraint.

N. All panels, cable trays, consoles, and equipment racks will be considered potential maintenance areas with the following criteria.

O. On-orbit repair will be considered for non-critical components (cameras, recorders, etc.). Repair of other components will be considered if repair of the component would be less complex than replacement or calibration, alignment, and adjustment is not required.

P. Equipment determined to be critical for crew life support or MSP survival will require onboard spares.

Q. MSP subsystem design concept to incorporate a fail operational/ fail safe philosophy thus increasing reliability with backup systems. As such, the maintenance of any given failure can be done on an as-required basis.

4.4.2 Reliability/Maintainability Approach

The objective of detail design effort will be to optimize the MSP in light of orbital maintenance philosophy, cost constraints, and Orbiter payload requirements. In order to accomplish this, an approach shown in Figure 4.4.2-1 will be used. Key analysis will include: subsystems, and system-level analysis to identify "weak links" of the system, Failure Mode and Effects Analysis (FMEA) to identify single failure points and component failure mode effects on the system, safety analysis to identify safety critical equipment and design issues that meet the minimum requirements of NHB 1700.7, plus trade studies to support objectives.

Since design concepts are developed in parallel with the reliability, maintainability and safety analysis efforts, it becomes necessary to develop and use an analysis method that will allow rapid evaluation of proposed design and design alternates in order to provide positive and timely design recommendations.

The heart of the analysis consists of a computerized math modeling technique. Inputs include: failure rate and duty cycle data, and a math model which summarizes and documents the equivalent impacts of a formal FMEA. This model is the equivalent of those described in MIL-HDBK-217 and can solve series, parallel, standby, binomial, Poisson or Bayes types of reliability models in any combination necessary to represent the system.

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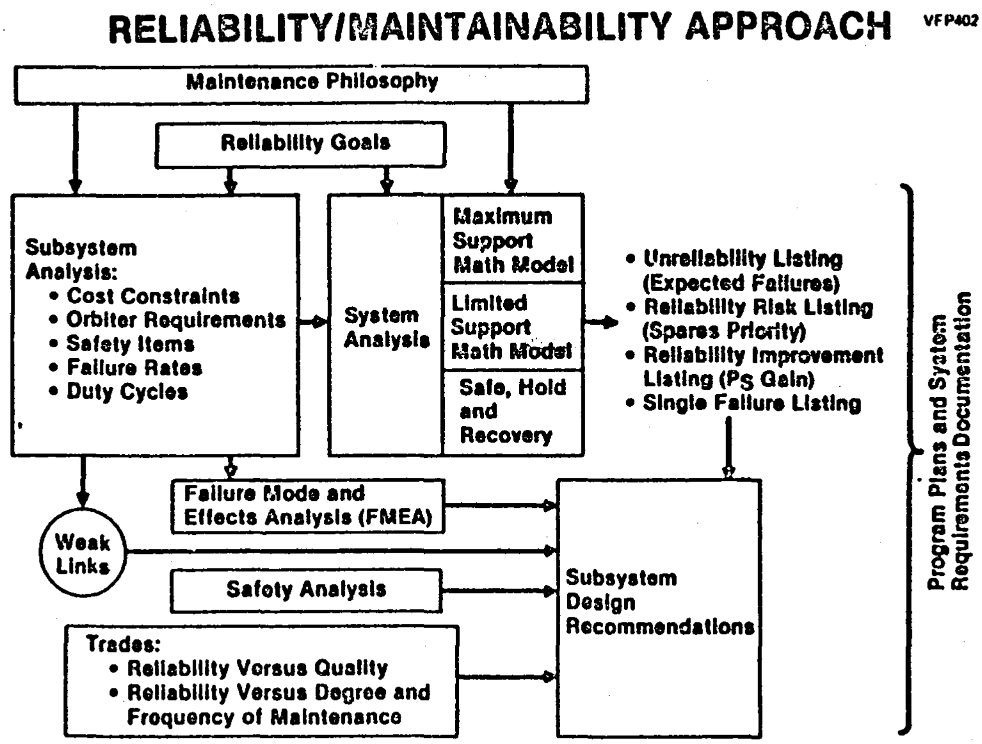
Figure 4.4.2-1

RELIABILITY/MAINTAINABILITY APPROACH



Outputs of the computerized models result in a direct calculation of the system reliability and number of expected failures with respect to any time inputs. A significant part of the solution output is a sensitivity analysis which indicates the direct change in the overall system reliability if any one component failure rate were ten times more or less than the value assumed in the basic input data.

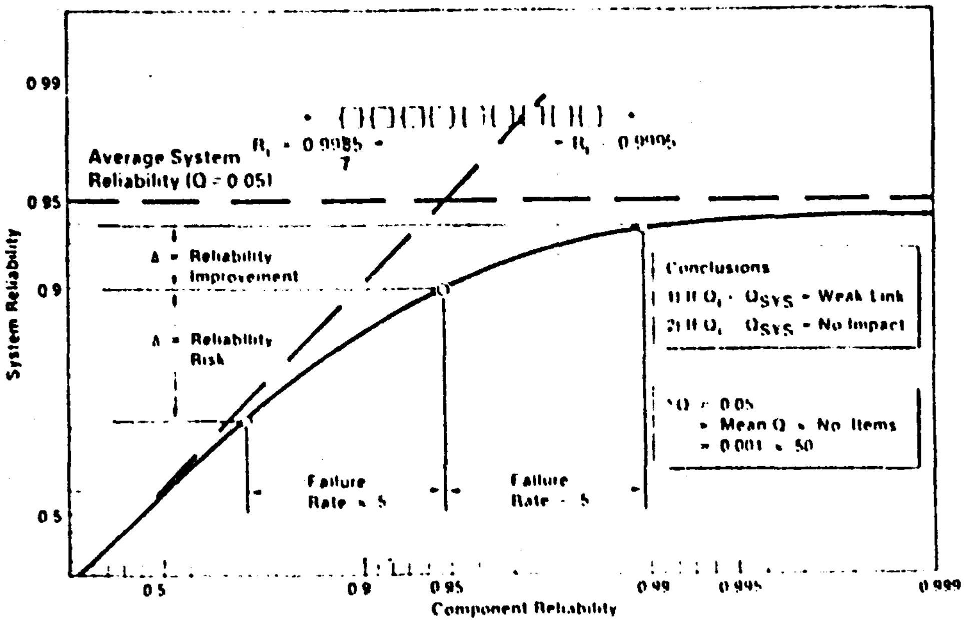
4.4.3 General System Analysis

4.4.3.1 Component Versus System Reliability

Figure 4.4.3.1-1 indicates the variation in subsystem (or system) reliability than can be expected when a single element (component) of the system is treated as a variable. This general model assumes that the system consists of many components that will range from .9975 to .9995 reliability resulting in a mean system reliability of approximately 0.95. When the component reliability is less than the system mean, the component becomes the "weak link" or driving

Figure 4.4.3.1-1

COMPONENT VS SYSTEM RELIABILITY FOR SERIES SYSTEM



element of the system. Conversely, when the component reliability is greater than the system mean reliability, other elements of the system become the "weak links" and it is not cost effective to attempt to improve the variable component reliability.

4.4.3.2 Reliability Versus Redundancy Versus Time

Figure 4.4.3.2-1 indicates the effects of making the weakest link system component redundant. The failure rate of the system component is assumed to be fixed at 10×10^{-6} failure/hour (this is an average failure rate of most "black boxes" that comprise a system). Since the basic system requirement is to eliminate single point failures, the lowest design level is the "1 of 2" curve. Redundancy curves with minimum operating to onboard equipment ratios greater than 0.5 (i.e., 2 of 3 or 3 of 4) represent "graceful degradation" rather than pure redundancy application. As demonstrated by the figure, additional redundancy can extend the life of the system from 2 to 5 years, but this is not the most efficient way to achieve better system reliability.

Figure 4.4.3.2-1

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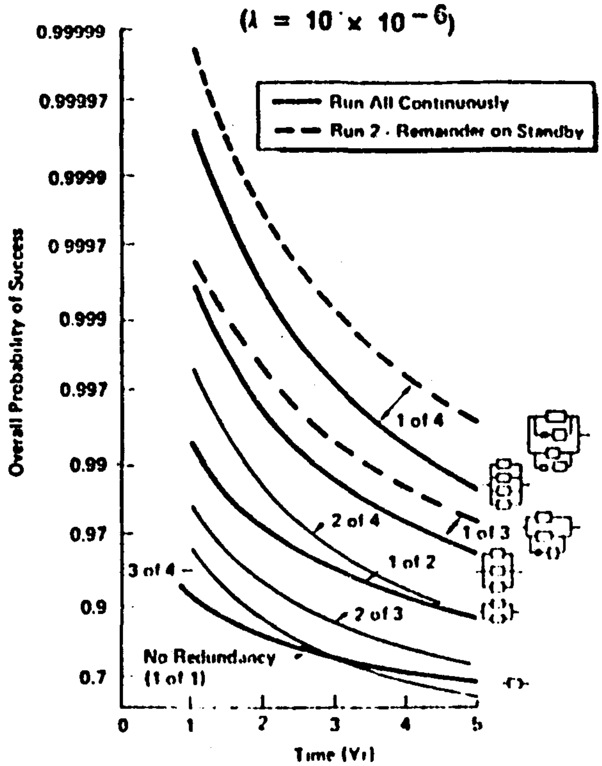
RELIABILITY VS REDUNDANCY

($\lambda = 10 \times 10^{-6}$)



4.4.3.3 Reliability Versus Failure Rate and Redundancy

The most efficient way to achieve long-term system success is through lowered equivalent item failure rates. Figures 4.4.3.3-1 and 4.4.3.3-2 indicate the probability of system success of a system as a function of the weak link component (equivalent item) failure rate and various designed-in active and standby redundancy levels. The figures indicate trends for 2 and 5 years, repsectively.

4.4.4 General Conclusions

The following conclusions result from the above general system analysis:

A. A quantitative math model coupled with a sensitivity analysis will be capable of identifying system "weak links."

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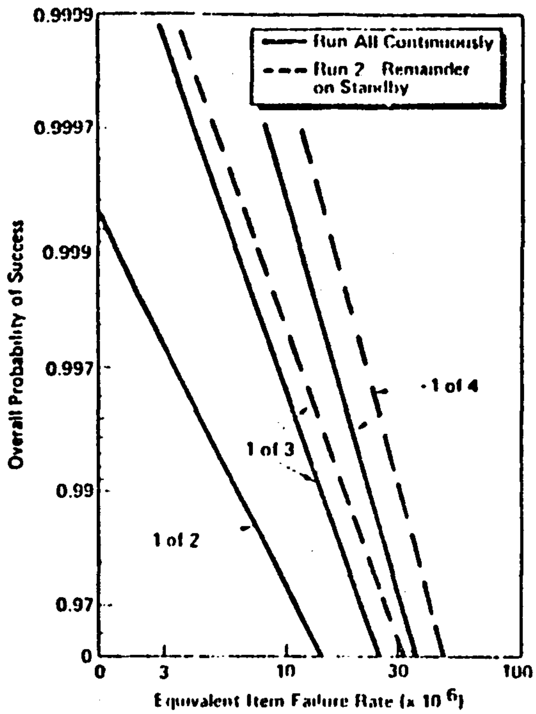
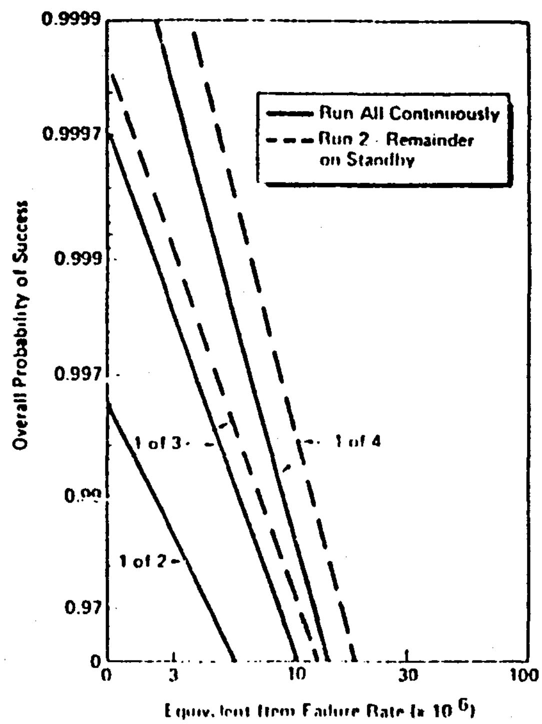
RELIABILITY
VS
FAILURE RATE
(2YR)

Figure 4.4.3.3-1



RELIABILITY
VS
FAILURE RATE
(5 YR)

Figure 4.4.3.3-2



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B. Designing redundancy into the high risk elements of the system can result in system improvements, but are not as cost effective as reducing the basic equivalent item failure rates (i.e., strive for the largest practical MTBF).

C. Low equivalent failure rates can be achieved by requiring internal redundancy in addition to potential unit level redundancy applications.

D. The most cost effective approach to a successful system is selecting parts of a high reliability quality level as practical.

Trade studies have been conducted on other programs, to explore the cost effectiveness of the "high reliability parts" approach. These studies concluded that by adopting a "selective screening" rather than "100% high reliability" parts procurement program, the MSP can achieve the equivalent to a high reliability program with a considerable parts cost saving.

4.4.5 Subsystem Evaluations

It will be necessary during the early portion of a preliminary design effort (Phase B) to make subsystem model evaluations to establish the basic characteristics of the system (i.e., reliability versus time), and identify weak links so that improvements can be considered and evaluated. The current concern is the projected reliability of the baseline two-segment Spacelab which has been selected as the habitat/payload module. The Spacelab has been designed with high reliability parts and redundancy complying with a design goal of 0.95 for a seven (7) day mission. The projected reliability is projected to be 0.9539 for seven days. If we project the reliability of the baseline Spacelab, without any modifications, to a thirty (30) day mission, the reliability level becomes 0.8028. It is clear that to assure a successful extended mission with the existing Spacelab design, chances to incorporate the capability for on-orbit maintenance is required. Inasmuch as we are starting with an existing Spacelab design, we must achieve the most effective improvement that is practical and economical. Thus, the approach should be based upon (1) making select design changes, (2) introduce built-in redundancies in problem areas, and (3) provide spares for replacement of equipment on-orbit.

A detail analysis of the Spacelab subsystem was performed by ERNO, first to determine the baseline reliability as a function of time. It was found to

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be very sensitive to time. It also was determined that the CDMS represented the most unreliability.

It will be necessary to perform a detailed reliability analysis to assure that the selected Spacelab subsystem has all the proper changes to permit it to accomplish the longer mission. Other factors should be included in future analyses. These factors include: (1) definition of the essential and non-essential equipment; (2) considerations of the operational cycle for the missions, reliability for a given item calculates to a higher value as it has less active mission time; (3) consideration of mass, volume, cost, etc., versus addition of spares or redundent units; and (4) considerations of degraded modes of operations for certain equipment - for example, if one key on the command keyboard fails, it is still possible to work around the problem.

4.4.6 Safety

In the early examination of new concepts such as MSP, safety awareness and considerations perform a very necessary function in alerting the designers to preventative design features that can be readily incorporated and can eliminate or control potential hazards during flight operations. During the conceptual study mission, functional activities were determined and allocated to various modules. These functional allocations are summarized in Table 4.4.6-1. These functions involved the incorporation of subsystems with potential hazard sources which influence their location. The proper support of a crew in a vehicle such as MSP requires a number of functions dedicated solely to crew support and safety including emergency provisions and hazard retreat areas. Contingencies are provided for in the MSP basic configuration and remedial safety aspects as onboard warning systems, 180-hour emergency supplies, 30-day contingency supplies, escape routes, and Orbiter rescue are included.

The approach to achieving an acceptable level of safety for the MSP has featured retreat-refuge (and recovery) rather than abandonment. Hazards have been minimized throughout design, operations and conceptual configuration effort, with special attention to location of potentially hazardous material. Backup provisions will permit operation of the MSP from either the habitat/payload module or the airlock/adapter module with full recovery

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Table 4.4.6-1
SAFETY
(MSP FUNCTIONAL ALLOCATIONS)

FUNCTION	MODULE				
	SPACE PLATFORM	HABITAT	AIRLOCK ADAPTER	LOGISTICS	PAYLOAD MODULE
• CREW SUPPORT					
. Eat	--	Prime	retreat	retreat	--
. Sleep	--	Prime	retreat	retreat	retreat
. Hygiene	--	retreat	Prime	retreat	--
. Atmosphere Storage	--		external	external	--
. H_2O Storage	--	internal (limited)	internal (limited)	internal (Prime)	--
. GN_2 & GO_2 Stores	--	--	external	external	--
. EC/LS	--	Controls	Controls	loop	loop
. EVA	--	--	Airlock	backup	backup
• OPERATIONAL SUPPORT					
. Thermal Service	Radiator	loop	loop	loop	loop
. Berthing Systems	PS/Orbiter PS/MSP	Module/ Module	Module/ Orbiter	Module/ Module	Module/ Module
. Elec. Power Primary	Solar Arrays controls	distrib. loop	controls distrib. loop	loop	loop
Emergency	Batteries	Batteries	Batteries	--	Batteries
. G&N Stab &	controls	Backup	sensors	--	--
. Propulsion	Reboost Module	--	--	--	--
. Communication (Ground Data & Voice Link)	Antenna Comm.	System	Comm.	Comm.	Comm.
. Control Panel					
Payloads	--	Prime	backup	--	--
Subsystem	--	backup	Prime	--	--
. Data Mgmt.	Space/ ground link	store relay	store relay	--	relay
. Spares	--	limited	limited	Prime	limited

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possibilities if retreat from either module is required. Every pressurized module berthed to the MSP is a safe refuge area for a minimum of 180 hours. If recovery from a contingency is not possible, Orbiter rescue is always available as the final backup.

A potentially catastrophic event which is always of concern in the environment of space is loss of atmosphere. Decompression can range from an explosive decompression to a relatively slow leak rate. Explosive decompression could result from a massive rupture of the pressure shall, blowout of a large view-port, or failure of a hatch.

The likelihood of occurrence of these events is extremely rare because of the safety factors incorporated in design which precludes operation of a hatch, and other fail-safe features.

Loss of atmosphere from smaller holes (at a critical, but not catastrophic rate) is far more probable. Typical causes could be module relief valve failed in open position, leakage at port or hatch, or meteoroid penetration. Table 4.4.6-2 provides estimates of probabilities for accidental loss of atmosphere of a module.

Figure 4.4.6-1 compares the time of pressure decay from 101 KN/m^2 (14.7 psia) to 59.3 KN/m^2 (8.6 psia). While this final pressure (equivalent to 94 mm Hg PO_2) is too low for sustained crew operations without acclimatization, it is a reasonable lower value. The crewmen would experience very little impairment at this pressure as they moved out of the module. Any symptoms of hypoxia can be alleviated by donning an emergency oxygen mask which is readily accessible in each module. Decompression sickness, the bends, would be no problem since a drop to approximately 360 mm Hg total pressure from 760 mm Hg can usually be tolerated safely. Susceptibility to bend varies somewhat with the individual.

The figure also shows the reaction times for evacuation of a module of various volumes. The 9552 cu/ft curve represents the total volume of the adapter, habitat, logistics and life science modules with all internal hatches open.

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Table 4.4.6-2

REASONS FOR DECOMPRESSION OF A MODULE

	Probability
Loss of seal at pressure hatch	0.0005
Loss of viewport	0.0010
Dumb/relief valves open	0.0016
Berthing collision	0.0003
Space debris collision	0.0005
Meteoroid puncture	0.0010
Overpressurization/rupture of pressure shell (explosion)	0.0006
Structural failure of pressure shell	0.0002
Corrosion of shell	0.0005
Internal puncture	0.0010

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Figure 4.4.6-1

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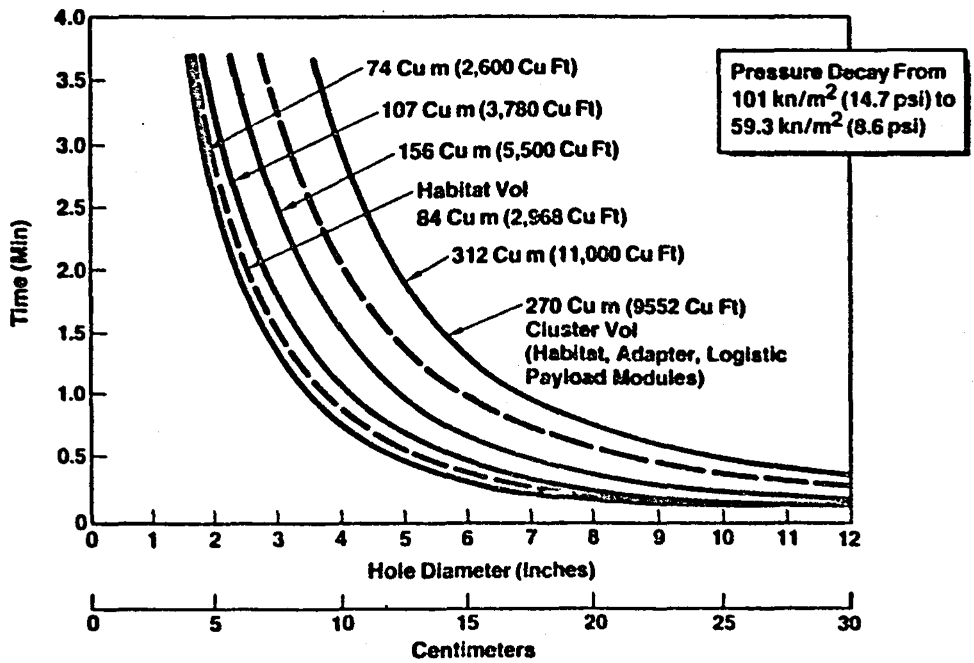
CREW REACTION TIME FOR WALL HOLE



No makeup atmosphere from onboard supplies is assumed for the decay rate. Note that a hole as large as 15 cm (6.0 in.) (equal to loss of viewport from hatch area) would still provide approximately one (1) minute of reaction time. The estimated time for crewmen to move the entire length of the habitability module would be eleven (11) seconds. This is considered the worst-case escape time since it assumes the crewman must move to the opposite end of the module. The time represents movement at 0.6m/sec (2 ft/sec) which could easily be accelerated under emergency all-out conditions.

Closure of the appropriate hatch can be accomplished rapidly; an estimate of 30 seconds or less is a conservative assumption. Addition of this time to the movement times still provides adequate time to evacuate the module. For holes in the equivalent size range of 2 inches or less, time is available for repair and evacuation of the module might not be required. Time needed for repair is a function of the location of hole and wall accessibility.

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Many hazardous situations requiring crew escape to a refuge area or requiring immediate corrective action for crew survival, will require detail safety analysis and operations hazard analysis to establish design and operational procedures. To provide an appreciation of a typical number of hazards that must be safely controlled, a hazard summary is shown in Tables 4.4.6-3 through 4.4.6-6. The following hazards are summarized: loss of module pressure, loss of O_2; fire and smoke; contamination, radiation, toxicity, buildup/activation, EVA/IVA, and explosion. An attempt was made, based on previous Space Station studies, to sequentially select the options available to the MSP crewmen if a hazard should occur. These options are shown in Table 4.4.6-7.

Ultimately, safety requirements must be imposed on all elements of hardware design and operational procedures. Figure 4.4.6-2 shows the general arrangement of the MSP three-man basic vehicle relative to the crew safety equipment, and Figure 4.4.6-3 summarizes the key safety features of the basic MSP configuration.

4.4.7 Meteoroid Protection Analysis

The MSP is expected to have a pressure shell construction consisting of Spacelab elements or a design quite similar to Spacelab. Therefore, the amount of pressure shell meteoroid protection afforded by the Spacelab design is a relevant quantity. This paragraph discusses the design requiremens for Spacelab and MSP and presents results of analyses to determine their meteoroid protection ability.

The design requirement for Spacelab is for a 0.95 probability of no pressure shell penetration (two-segment) for an exposure period of 350 days. This time period corresponds to 50 missions of 7 days each. The same probability of puncture (0.95) was accepted for MSP, except mission time was increased to 10 years (3,643 days) and number of two-segment modules was increased to four.

Detailed analysis of Spacelab was performed using optimum bumper solution method by Burton G. Cour-Palais. The results show a probability of no puncture of 0.9944 compared with the required 0.95 value. If this design is extrapolated to MSP design requirements, a value of 0.79 results which is considerably below the requirement.

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Table 4.4.6-3

HAZARD ANALYSIS - LOSS OF MODULE PRESSURE

Failure Event	How Occurring	Recommended Action
Dump and relief valves fail to open or inadvertently open. Airlock equalization valves or air ducts inadvertently opened.	Human error. Seat contaminated or deteriorated. Galling or solenoid failure.	Provide capping or fail-safe design for valves which can open to space environment. Manual closure possible. Provide for replacement of embrittled seals. Provide for contingency procedure in the event valves fail to open (e.g., use masks, move to other compartment, close hatch).
Rupture of pressure shell	Overpressure from broken O_2 or N_2 line, pressure control valves failed in open position.	Locate pressure tanks in module isolated from habited modules. Provide redundant relief devices. Backup sensing/control alarm system Manual override Size relief valves to handle condition. Pressure shell safety factor of 2 to 1.
Berthing collision causing pressure shell or hatch damage	Thruster failure. Pilot error. MSP orientation disturbance.	Fail-safe thruster design. Independent braking thrusters. Redundant berthing aids. Automatic shutoff of propellant flow to thruster if duration exceeded.

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Table 4.4.6-3

HAZARD ANALYSIS - LOSS OF MODULE PRESSURE (continued)

Failure Event	How Occurring	Recommended Action
		Berthing safety officer Contingency (backoff) procedures
Viewport seals, EVA hatches, berthing ports, etc., fail.	Seals degrade and embrittle. Rupture of viewport.	Redundant seals Provide for scheduled replacement. Provide contingency procedure for closing off compartments in event of severe leaks. Monitor total pressure and provide audible or visual alarm if pressure deviates from certain limits. Provide sensors to detect leakage of pressure through leak and pressure shell. Use large safety factor.
Meteoroid puncture, space debris puncture, internal puncture.	Cargo-handling accident. Fragments from explosion.	Provide detectors to locate puncture. Provide patch kit. Contingency procedure which enables crew to egress rapidly from compartment in event of large hole and rapid venting to space. Provide shielding for pressure vessels. Cargo-handling aids.

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Table 4.4.6-4

HAZARD ANALYSIS - LOSS OF MODULE PRESSURE - EXPLOSION

Failure Event	How Occurring	Recommended Action
Rupture or burst of following components located in Habitat, Logistics Module, Airlock/Adapter	Relief valves fail to open	High burst-to-operating pressure safety factor
	Ding in tanks creates high stress point	Redundant relief devices
O_2, N_2 gas	Human error - Crewmen hits tank with tool	Subject components to (1) special handling and shipping controls, (2) double inspection, (3) labeling, (4) tight test controls
Pressurant lines		
Pressure regulators	Damage by cargo movement	
Emergency O_2 tanks	Meteoroid puncture	
		Shield pressure vessels to avoid chain reaction if one bursts
Freon accumulator	Poor weld joint	
Portable life support system	Metal or weld fatigue	
		Design anti-shrapnel pressure vessels
	Break in lines	
CO_2 accumulator		
	RF energy present from RF filter failure	Locate in unpressurized compartment
Batteries of black boxes rupture		
	Internal short results in overheating	Isolate behind pressure bulkheads
		Fail-safe filter design
		Provide double stainless steel cases for battery and relief devices for black boxes

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Table 4.4.6-4 (continued)

HAZARD ANALYSIS - LOSS OF MODULE PRESSURE - EXPLOSION

Failure Event	How Occurring	Recommended Action
Combustible gases or powders in presence of ignition source	Static charge buildup Electrical short Gas leakage	Provide venting and purging for gases to preclude buildup Provide means to constantly ground crewmen Ensure that all hazardous experiment are conducted in controlled areas Provide for monitoring of gases Provide protection against any ignition sources

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Table 4.4.6-5

HAZARD ANALYSIS - LOSS OF MODULE PRESSURE —
FIRE, SMOKE, TOXICITY

Failure Event	How Occurring	Recommended Action
Battery fluid or gas leakage	Overheating or internal shorting could cause outgassing and leakage of KOH	Provide sensors in vicinity of batteries
		Contingency procedure to get rid of KOH if leakage occurs
Electrical initiation	Power distribution wire short	Protect with circuit breakers or fuses
	Electronic equipment boxes explodes or outgases	Design boxes to prevent overpressure
		Use fire and smoke detectors near potential fire sources
		Provide automatic or readily accessible fire extinguishers
		Provide contingency procedure for fire or toxicity
Static electricity	Metal tools, etc., in contact with equipment	Arcproof tools or coated tools. Ground all equipment that can arc
	Charge buildup in clothing	Procedure ground crewmen before metal contact
	Inadequate grounding of equipment	

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Table 4.4.6-5 (continued)

HAZARD ANALYSIS - LOSS OF MODULE PRESSURE -
FIRE, SMOKE, TOXICITY

Failure Event	How Occurring	Recommended Action
		Provide shutoff capability and the capability to purge area
		Vent all connections overboard
		Provide sensors to detect pressure
		Provide fire detection sensors and a fire suppressant system
		Minimum use and rigid control of combustible materials
Toxic fluid leakage	Piping breaks, piping connector leakage, container rupture, spill	Provide sensors and warning devices
		No toxics in normally habited areas
		Provide shutoff capability and a capability to purge potentially affected areas
		Toxics in special isolation chamber

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Table 4.4.6-6

HAZARD ANALYSIS - LOSS OF MODULE PRESSURE - CONTAMINATION

Failure Event	How Occurring	Recommended Action
High toxicity buildup	Materials outgas and removal devices fail or are inadequate	Provide redundant contamination removal capability
	Caution and warning unit fails to indicate buildup	Provide redundant caution and warning capabilities
		Use strict materials control during design
		Provide temporary (masks, etc.) emergency provisions
		Provide monitoring and alarm capability and crew escape procedures
Pathogenic	Experiments	Isolate from space station habited areas. Separate or isolatible EC/LS for specimens. Work in safety cabinet or enclosed hooded bench. Maintain lower pressure in work areas.
		Follow standard micro-biological safety requirements
	Contaminated water	Bacteria filter
		Pasteurization
		Purity test

Table 4.4.6-6 (continued)

HAZARD ANALYSIS - LOSS OF MODULE PRESSURE - CONTAMINATION

Failure Event	How Occurring	Recommended Action
CO_2 buildup	Failure of CO_2 removal unit (valves, controls, etc.) and failure of caution and warning unit	Redundant CO_2 removal units
Trace contaminants	Failure of trace contaminant control unit (Li_2, CO_3, sorbeads, charcoal, fan, catalytic oxidizer) and failure of monitoring and warning unit	Redundant trace contaminant units

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Table 4.4.6-7

EMERGENCY PROCEDURE ANALYSES

Emergency Condition	Reaction Time	Possible Emergency Response
Inadequate oxygen:		
1. Loss of total pressure in one pressurized module	Minutes to days	Warn crew of emergency
		Evacuate module
		Seal it from other modules
		Don pressure suits, reenter module
		Locate source of atmosphere loss
		Effect necessary repairs and and repressurize
2. Loss of total pressure in Habitat and Adapter	Minutes to days	Warn crew of emergency condition
		Evacuate to Logistics Module, Payload Module or Airlock
		Don pressure suits and reenter module
		Locate sources of leakage
		Effect repairs and repressurize
3. Shortage of O_2 in a compartment with normal total pressure	Hours to days	Evacuate module and reference other modules to other EC/LS
		Don emergency O_2 masks
		Reenter compartment and repair fault in EC/LS
		Permit O_2 level to increase to a safe level before reentering module.

Table 4.4.6-7 (continued)
EMERGENCY PROCEDURE ANALYSES

Emergency Condition	Reaction Time	Possible Emergency Response
4. Failure open of dump and relief valve	Minutes	Manually close valve
		Repressurize compartment
		When it is impossible to immediately close valve. warn remainder of crew
		Evacuate module
		Seal off module
		Reference other modules to other EC/LS system
		Don pressure suits and reenter
		Close and repair dump valve
		Repressurize module
5. Failure of PLSS to supply viable atmosphere to EVA astronaut	Seconds to Minutes	Apprise buddy of emergency situation
		Immediately head to EVA airlock with assistance of other astronaut
		Notify onboard crew to have emergency oxygen ready as soon as airlock opens
		While airlock is repressurizing, buddy plugs into umbilical outlet in airlock
		Administer oxygen to man
		Take man to first aid area when airlock opens

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Table 4.4.6-7 (contined)

EMERGENCY PROCEDURE ANALYSES

Emergency Condition	Reaction Time	Possible Emergency Response
Astronaut becomes ill or injured during EVA	Seconds to Minutes	The buddy who is always in visual contact assists endangered man and assures he reenters via EVA airlock as soon as possible. Man then taken for medical treatment. If man's condition is too severe to be treated, then sends him down via Orbiter emergency flight.
Contamination:		
1. Compartment contaminated with substance which is filterable by EC/LS	Minutes to days	Warn crew of dangerous situation. Evacuate module and seal it from remainder of MSP. Don pressure suit and reenter compartment. Eliminate source of contamination. Wait for EC/LS to clear the atmosphere (approx. 2 hr).
2. Compartment contaminated with substance which is not filterable by EC/LS	Minutes to days	Warn remainder of crew of dangerous condition. Evacuate module and seal it from remainder of MSP. Don pressure suits and reenter compartment.

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Table 4.4.6-7 (continued)

EMERGENCY PROCEDURE ANALYSES

Emergency Condition	Reaction Time	Possible Emergency Response
		Empty by opening dump valves.
		Eliminate source of contamination.
		Close dump valves and repressurize.
3. Excessive CO_2 in a module	Hours to days	Evacuate module and reference other modules to other EC/LS.
		Don O_2 masks and reenter module.
		Repair failure in EC/LS system.
		Vacate module and wait until CO_2 level is back to tolerable level before reentering.
Radiation:		
Abnormal high flux of protons generated from solar flare activity	Minimum of 2 hours from onset to maximum flux	Personnel move to positions for additional shielding.
		Operating crew don EVA suits for additional shielding.
Collision between Orbiter, MSP, Logistics vehicle, Payload module, or space debris	Minutes to days	See Item 1 and 2 under inadequate oxygen.

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Table 4.4.6-7 (continued)

EMERGENCY PROCEDURE ANALYSES

Emergency Condition	Reaction Time	Possible Emergency Response
Fire:		
1. Small isolated fire suitable for automatic or manual fire suppression	Minutes	Turn off equipment which may contribute to the fire.
		Put out fire by use of a fire suppressant system.
		EC/LS purge compartment.
2. Large conflagration which is beyond the scope of fire suppressant devices	Seconds to minutes	Warn remainder of crew.
		Personnel don emergency oxygen masks.
		Turn off equipment which can contribute to the fire.
		Evacuate module and isolate from remainder of MSP.
		Purge compartment by remotely opening dump valves.
		Repressurize and reenter.
Nitrogen or oxygen pressure vessel rupture in unpressurized compartment in Logistics Module	Minutes to hours depending on damage	If pressure integrity of pressurized section of Logistics Module is maintained, then
		Don space suits
		Enter pressurized section and depressurize
		Open hatch and enter explosion area
		Effect repairs

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Table 4.4.6-7 (continued)

EMERGENCY PROCEDURE ANALYSES

Emergency Condition	Reaction Time	Possible Emergency Response
		If the pressurized section has been ruptured, then
		Don space suits
		Go through airlock and enter damaged area.
		Repair damage to pressure hull..
		Repressurize and complete repairs.

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Figure 4.4.6-2

BASIC THREE-MAN MSP SAFETY EQUIPMENT SUMMARY/LOCATIONS

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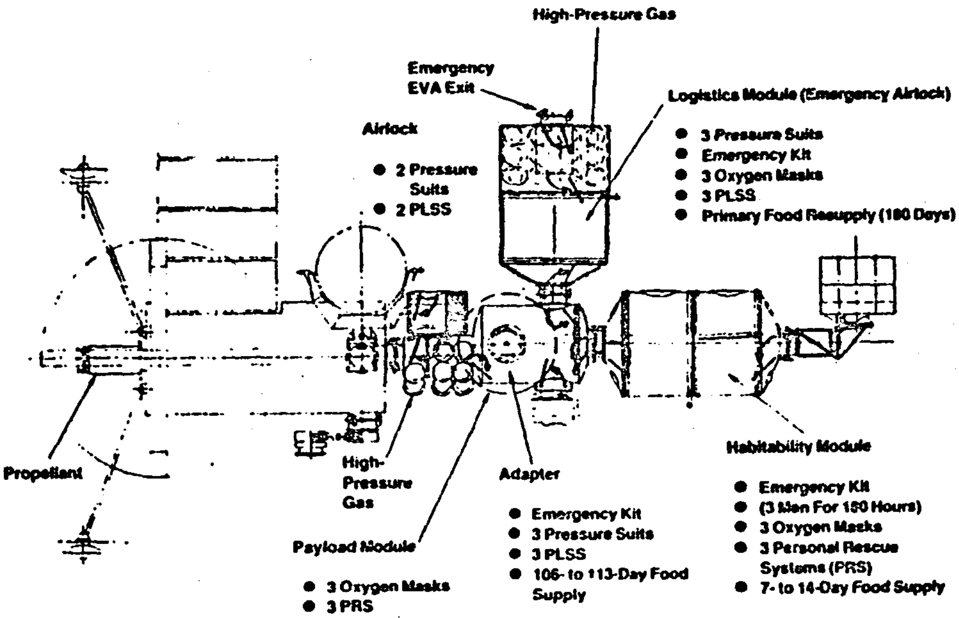

Figure 4.4.6-3

KEY SAFETY FEATURES OF BASIC CONFIGURATION

- 2 Separate Pressurized Habitable Volumes
- Separate Subsystems for Each Volume
- Repressurization Stores For Largest Pressurized Volume
- 3 Isolated Power Source Buses
- Emergency Power Distribution Provided
- Overpressure Protection and Emergency Atmosphere Dump Capability in Each Pressure Volume
- Critical Subsystem Functions Are Fail-Operational/Fail-Safe
- EVA Rescue Routes Provided in Each Separate Habitable Volume

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An ERNO-proposed modification, shown in Figure 4.4.7-1, increases standoff between wall and bumper and places a second fiberglass cloth on the bumper. MDAC analyses results are shown in Figure 4.4.7-2 for cases with and without viewports and windows and varying mission duration. The MDAC results give a value of 0.984 with no windows and 0.9697 with windows. The results are very slightly lower than the ERNO results, probably accounted for by small differences in assumptions.

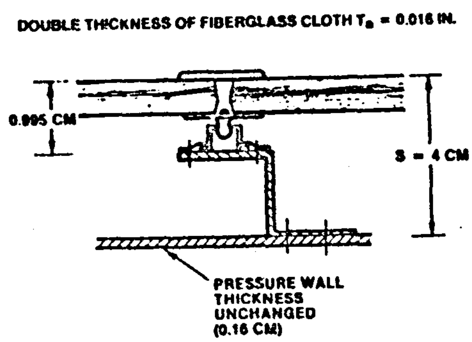
Past experience with past space programs has shown the difficulty of accurately predicting meteoroid penetration limits. Therefore, a ballistic test is recommended early in the MSP program to more accurately determine the adequacy of the ERNO-proposed meteoroid bumper. This test is particularly called for with the Spacelab design which uses fiberglass cloth material whose behavior is difficult to predict, based on extrapolations to equivalent aluminum sheet as required by the analysis.

Figure 4.4.7-1

VFO638

SPACELAB
METEOROID PROTECTION ANALYSIS

- ERNO-Proposed Configuration
- Spacelab Requirement Is 0.95 Probability for 350 Days
- 0.95 Probability for Four 2-Segment Modules for 10 yr Requires 0.987 Per Module
- Analysis Method According to Burton G. Cour-Palais



MODIFIED SPACELAB WALL

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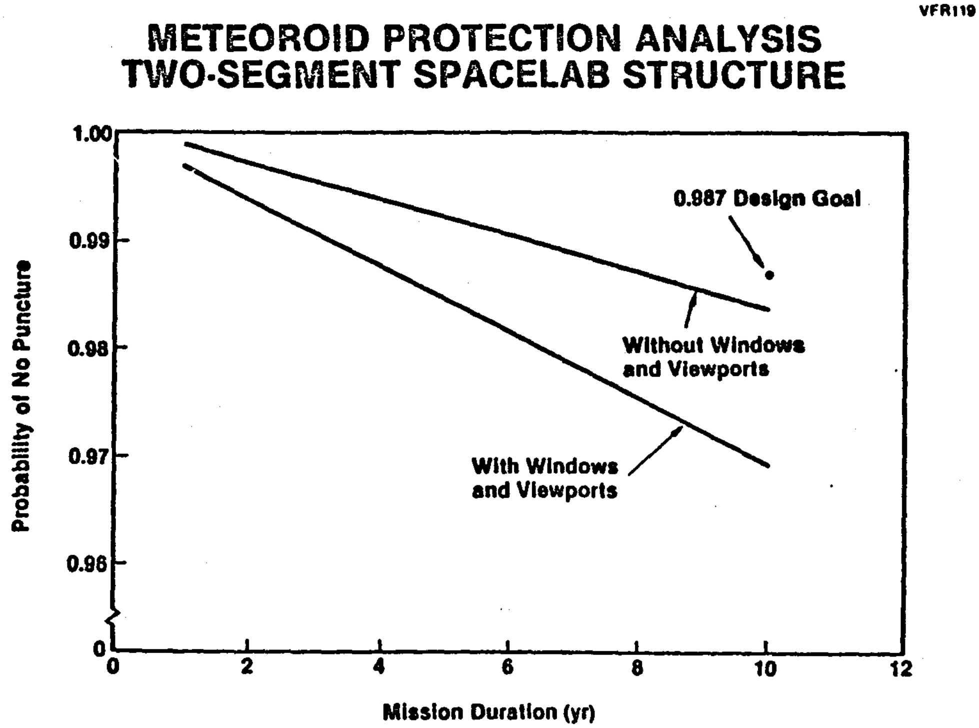
Figure 4.4.7-2



An analysis was also performed to estimate meteoroid damage to high performance insulation around the exterior of the pressure shell. The insulation was assumed to be positioned adjacent to the inside of the meteoroid bumper. A meteoroid which penetrates the bumper would make a small hole in the outside of the insulation, but the damage would extend out in a 30° core as the meteoroid passes into the insulation.

The damage caused by the meteoroid is shown in Figure 4.4.7-3 as a function of shield (bumper) thickness. Results show for the ERNO-proposed design that less than 1 percent of the insulation would be damaged in 10 years. Based on this very small damage, it is believed that insulation damage by meteoroids is not a significant problem.

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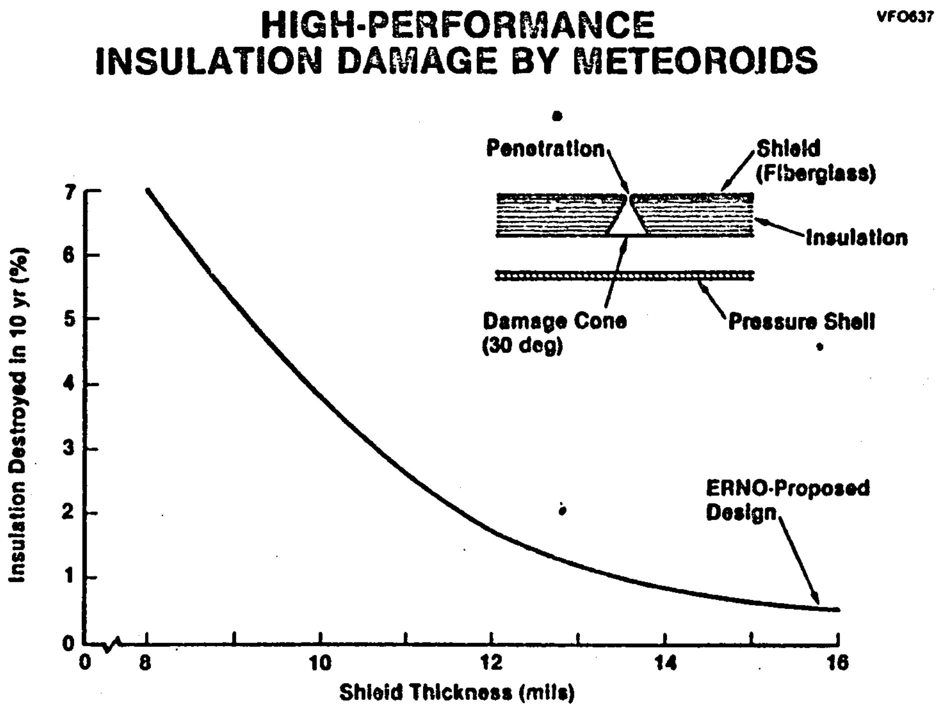
Figure 4.4.7-3



4.5 SUBSYSTEM DEFINITION

4.5.1 Summary and Conclusions

This paragraph presents the detailed definition of subsystems for the Basic Manned Space Platform. Detailed hardware characteristics are tabulated in terms of weight, volume, power and equipment arrangements. The extent and rationale for "use of existing hardware" is described with regard to applicability, required modifications and availability in the platform era. Problem areas are discussed along with remaining issues and major program impacts of the subsystem designs.

The subsystem design emphasizes use of existing hardware where practical in order to achieve low initial cost and program risk. Since the Spacelab module is being recommended as the basic pressurized module of the MSP, use of Spacelab subsystems is particularly attractive because these subsystems are already integrated and qualified as a unit thereby greatly reducing cost.

Particular care was taken in the study to assure interface compatibility with the Power System and the Orbiter. Results of the interface design are included in Paragraph 4.6.

The Environmental Control/Life Support subsystem is designed around the existing Spacelab upgraded as indicated by the increase mission duration to decrease the high expendable needs of the Spacelab approach. The extended mission time also requires other modifications for maintenance provisions, high reliability and contaminant control. This extensive use of Spacelab equipment results in a low-cost and low-risk program but the design is a "no throw away" approach which adapts efficiently to the use of a more advanced closed-loop concept.

A CDMS concept has been defined that provides the necessary communications and data management support and services for the manned platform with low technical risk by making use of existing Spacelab and Shuttle hardware designs where possible. New hardware has been defined only in those cases where existing Spacelab or Shuttle hardware is not available for the needed function. These cases are mostly related to Power System interfaces.

Two concerns with the CDMS approach remain: (1) the reliability that is attainable for long-duration missions with Spacelab and Shuttle hardware and (2) the cost and performance penalties that are associated with using 1970s electronics technology rather than the technology of 1985 or later. These concerns have not been addressed quantitatively. It is recommended that future manned platform studies investigate alternate CDMS approaches with particular emphasis on these concerns.

The electrical power subsystem (EPS) concept is designed to satisfy the basic functional and program requirements to accommodate existing payloads and equipment in a nominal 25 kW Power System configuration. Initially, regulated 30 VDC power will be delivered to the Airlock/Adapter (A/A) for distribution to the Habitability Module (H/M) and to specified attached payloads (Spacelab Module shown for reference). Power is also distributed to payloads (experiments) carried within the H/M. A three-bus 30 VDC interface is provided at the Orbiter berthing port to supplement Orbiter power in either a Shuttle-tended or sortie mode.

In addition to the 30 VDC main power bus interfaces, two 30 VDC auxiliary buses are provided at the A/A payload ports for essential and emergency power. Provision is also shown for supplying emergency power from the A/A to the H/M. AC power is supplied locally.

Interfaces shown for the initial version are suitable for either the 12.5 kW or 25 kW Power System. Growth provisions include an additional 30 VDC bus from the A/A to the attached payload module and up to three 30 VDC and three 120 VDC buses for payloads supplied via the H/M and second Airlock/Adapter. Emergency power is rederived from the 30 VDC main power buses in the second A/A for distribution to subsystems and payloads, as in the initial configuration.

The conceptual design for the structural/mechanical subsystem was directed toward the MSP primary and secondary structural configuration for three major elements: (1) Habitability Module, (2) Adapter/Airlock Module and (3) Logistics Module. Available hardware was selected for each possible major element. However, detail design analysis must be conducted to verify the structural integrity of the available elements and to identify any modifications required peculiar to the MSP.

Concepts to provide habitability functions were selected to assure the psychological and physiological well-being of the crew. This is accomplished without undue penalty to the MSP or without diluting resources available to experiments. Full use was made of suitable existing hardware and technology.

Essentially, existing concepts are used in the design which have been proven on past programs or will be proven early in the Shuttle program. Food concept is a combination of the Skylab and Shuttle concepts of shelf-stable storage approach supplemented with frozen foods and limited fresh foods. An improved version of the Skylab full-body shower is also planned. Most of the remaining habitability provisions will be Shuttle program derivative.

4.5.2 Environmental Control and Life Support

The Environmental Control and Life Support (ECLS) subsystem maintains a viable atmosphere for the crew and provides for thermal control of payload and vehicle equipment. Specifically the total pressure and composition of the atmosphere are controlled by the Atmosphere Supply and Control Section (ASCS). The Atmosphere Revitalization System (ARS) maintains a viable atmosphere by providing cooling, carbon dioxide removal, humidity control, trace contaminant control and debris filtering. Continuous atmosphere circulation prevents stagnation and promotes forced convection cooling.

Water is provided to the crew for food preparation, drinking and personal hygiene. Most of this water comes from resupply stores and a smaller amount is reclaimed from condensate for crew hygiene.

Thermal Control is accomplished actively by circulating fluid loops which collect MSP heat and transport it to the Power System where it is rejected to space. Passive thermal control devices are incorporated where appropriate and these include thermal coatings, insulation and electrical heaters. Support is provided for both Intravehicular and Extravehicular Crew Activity (IVA/EVA) and fire detection and suppression provisions are incorporated in the design.

In this portion of the study, Hamilton Standard supported several tasks involving use of existing hardware, solid amine and water recovery trade data and mass balances.

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In the following paragraphs, the selected ECLSS design will be described along with the supporting trades and analyses which lead to the design.

4.5.2.1 Subsystem Definition

The Environmental Control/Life Support subsystem is designed around the existing Spacelab upgraded as indicated by the increased mission duration to decrease the high expendable needs of the Spacelab approach. The extended mission time also requires other modifications for maintenance provisions and contaminant control. This extensive use of Spacelab equipment results in a low cost and low risk program but the design is a "no throw-away" approach which adapts efficiently to the use of a more advanced closed loop system.

4.5.2.1.1 Description - The concepts selected and their arrangement in the initial configuration is shown in Figure 4.5.2.1.1-1. All key functions are duplicated in the Airlock/Adapter and the Habitability Module in order to satisfy the requirement for two separate pressurizable compartments with independent ECLS. Each compartment is provided with a Spacelab ECLS

Figure 4.5.2.1.1-1

HAMILTON STANDARD

BASIC MSP ECLS EQUIPMENT LOCATION

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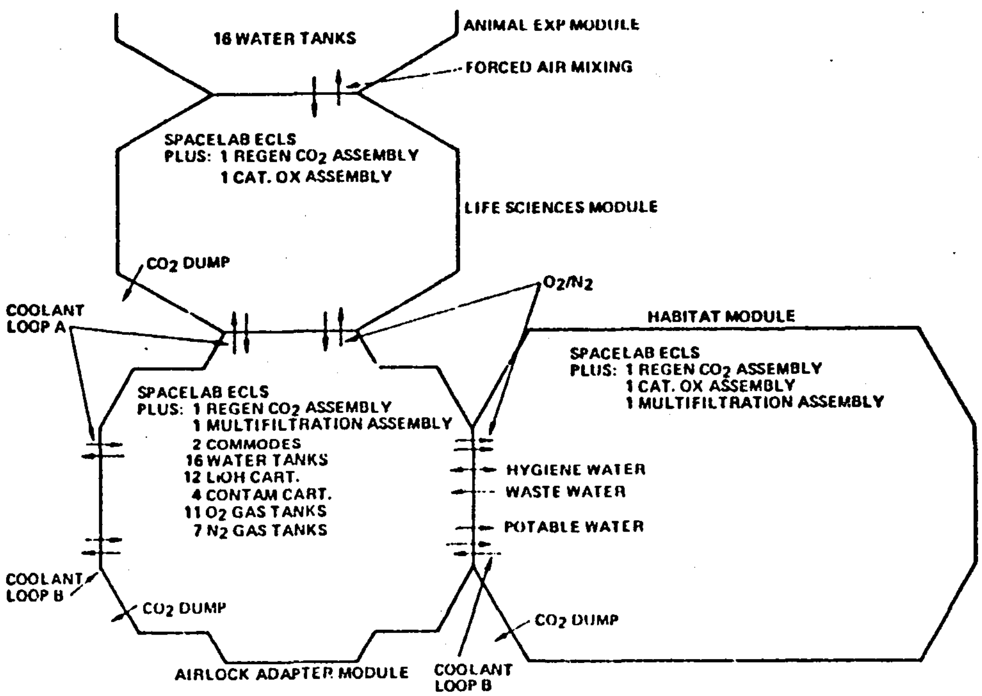

consisting of an Atmosphere Storage and Control Subsystem (ASCS), Atmosphere Revitalization Subsystem (ARS) and active and passive Thermal Control Subsystem (TCS).

The ASCS provides for supply and control of the module atmosphere pressure and composition and provides for positive and negative pressure relief. It maintains a two-gas oxygen/nitrogen atmosphere which approximates earth surface conditions and is compatible with the atmosphere of a docked Orbiter crew compartment. Specifically, the ASCS provides the following functions.

- Storage and supply of gaseous nitrogen required for the makeup of module leakage and airlock operation.
- Storage and supply of gaseous oxygen required for metabolic consumption, leakage makeup and airlock operation.
- Prevention of excessive module positive and negative pressure differentials.
- Module depressurization and bleed in the event of contingencies.
- Venting for evacuation of experiment chambers.
- Provide signal outputs for monitoring and evaluating the performance of the equipment.

Gaseous N_2 and O_2 will normally be provided from tanks on the logistics module; initial and contingency stores are located around the periphery of the Airlock/Adapter. The oxygen and nitrogen tanks are Orbiter-derived spherical tanks consisting of a metal liner with a Kevlar/Epoxy composite overwrap. The tanks will be arranged in two separate banks each with a separate supply system to the two separate compartments. Sufficient contingency supplies are provided to repressurize the largest compartment and provide for 90 days contingency supply.

The air within the modules is maintained in a conditioned stage by the ARS which controls temperature, humidity, odor, contaminant, carbon dioxide, air circulation and particulate matter. This subsystem also provides for the required air circulation and fire detection and suppression.

Air from the module is drawn through a 300-micron particulate filter by the redundant cabin fans. Normally only one fan is operating, backflow through the inoperative unit is prevented by check valves. Downstream of the fans the air flows through charcoal conisters for odor removal. These canisters are contained in the Spacelab CO_2 control assembly which in the platform application is used for odor control. During contingency modes of operation, the charcoal canisters are replaced by lithium hydroxide canisters which remove the CO_2.

A portion of the downstream air is withdrawn to the solid amine CO_2 control unit for CO_2 removal. This is a water-save regenerable concept with steam desorption of the CO_2 to space. The solid amine bed is the major component in the system. It holds the IRA-45 granular amine material.

Air flow during adsorption is provided by a fan and controlled by three air valves. Two valves are either open or closed while the third is used to modulate canister flow by venting a portion of the air around the canister.

During desorption, the two large canister valves close and the flow sensor loop is opened. Water is pumped to the integral bed steam generator which converts the water to superheated steam. The steam wave pushes residual air out of the bed at a low flow rate as the steam moves through the bed. As the steam reaches the end of the bed, a high purity (99%) CO_2 wave evolves off the in-flow and switches the CO_2 flow either overboard to to a CO_2 reduction regulator in the CO_2 outlet. The desorption process is controlled to the saturation temperature of steam at the regulated pressure which is baselined at 212°F and 14.7 psia.

A controller/sequencer is used to time and sequence the various valving, pumping and fan flow activities. The controller will also assist in fault detection and automatic shutdown sequencing.

The ARS process air next passes to the condensing heat exchanger where it is cooled and dehumidified. The condensing heat exchanger is a cross-counter flow plate fin unit made of stainless steel. Cold water from the thermal control subsystem is circulated on the liquid side. As the air is cooled, condensation occurs within the air passages which are coated with a hydrophilic agent to promote "wetability." As a result the air flow forces the condensate to the exit end where it is removed by a "slurper" device.

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Temperature control is obtained by bypassing air around the heat exchanger to obtain the required heat exchanger exit air temperature. This control consists of a motor actuated flapper valve, a controller and temperature sensors. The electrical components in this unit are redundant.

A catalytic oxidizer has been incorporated in the design to control contaminants not removed in the odor control canisters. The assembly consists of a presorbent bed, a fan, regenerative heat exchanger, a high temperature catalytic oxidizer and a post sorbent bed. Air is drawn into the presorption bed containing lithium hydroxide which removes acid gases which could poison the catalytic oxidizer. The air then flows through the regenerative heat exchanger where the temperature is increased. Downstream an electrical heater increases the air temperature further prior to passing through the catalyst canister where contaminants are oxidized. Post sorbent beds containing lithium hydroxide and purified remove the products of contaminant combustion.

A mixture of condensate and air is drawn from the condensing heat exchanger by the water separator. This unit consists of two integral rotary drum/fan components; the fan draws the air through the unit. Condensate is separated from the air in the rotating drum, removed with a stationary pitat tube and directed to water management subsystem. Backflow of condensate is presented by check valves.

Normally only one separator is operating while the second unit is on standby. Backflow of air through the inoperative unit is prevented by check valves.

A Spacelab avionics loop is provided in the habitability module for air cooling rack-located avionics. Cooling air is directed to the racks through a duct system to the racks. Flow balancing and flow to each rack is controlled by adjustable shutoff valves. Air circulation within the loop is provided by the avionics fan assembly which consists of two redundant fans with check valves to prevent backflow. Air leaving the fan assembly passes through the avionics heat exchanger where it is cooled prior to being directed back to the racks.

Multifiltration condensate recovery units have been added in each compartment to provide water for personal hygiene and solid amine CO_2 control desorption. This unit reduces the required water resupply by 34.3 lbs/day and also reduces waste storage and earth return requirements. The multifiltration unit consists of filters, charcoal and ion exchange resin beds to remove impurities.

Potable water needs are provided by resupply water which is normally stored in tanks located in the logistic module. A 90-day initial and contingency supply is located in the Airlock/Adapter. The contingency water supply is manifolded separately from the normal resupply so that a failure in one supply will not propagate to the second supply.

The water supply tanks located in the logistics module also act as waste water return tanks. After fresh water is removed from the tanks, they are filled with waste water. This approach keeps logistic module volume and tank cost to a much lower level, however, development effort is necessary to ensure that fresh water supplies are not inadvertently contaminated by the waste water. This approach will also require additional ground servicing to render the tanks sterile and uncontaminated prior to filling with potable water resupply.

Water is supplied to the galley and water dispensers for food preparation and crew drinking. Also a small quantity of potable water resupply becomes makeup in the personal hygiene loop.

Separate atmosphere revitalization subsystems will be provided in the experiment modules. This will consist of a Spacelab ECLS with regenerative CO_2 control and catalytic oxidizers. Separate water supplies will be provided if required by the payload such as in the case of Life Science Payloads.

4.5.2.1.2 Characteristics - Table 4.5.2.1.2-1 gives the ECLS subsystem characteristics for the initial configuration consisting of the Airlock/Adapter, Habitability Module and the Logistics Module. The values given do not include supporting structure and monitoring instrumentation. The equipment shown in the table weigh a total of 3316 lbs and consume an average power of 3584 watts.

Table 4.5.2.1.2-1

ECLS SUBSYSTEM CHARACTERISTICS - INITIAL CONFIGURATION

Equipment	No. Req'd	Weight (lb)	Volume (cu ft)	Power Ave/Peak (watts)	Location
N_2 Tanks	6	336	28.5	--	A/A
O_2 Tanks	12	672	56.9	--	A/A
Fill and Relief	Set	3	0.1	72/72	LM, A/A
O_2/N_2 Panel	2	108	4.6	34/52	A/A, HM
Vent and Relief Valves	3	33	3.3	84/90	LM, A/A, HM
Sensor Panel	2	20	0.7	10/10	A/A, HM
Lines and Disconnects	Set	6	0.05	--	A/A, LM, HM
Cabin Fan Assembly	2	82	5.8	790/790	A/A, HM
Condensing Heat Exchanger	2	86	5.6	--	A/A, HM
CO_2 Control	2	134	8	210/420	A/A, HM
Odor and Cabin Temperature Control	2	80	13.4	68/68	A/A, HM
Condensate Separator	2	43	2.9	96/96	A/A, HM
Condensate Processor	2	330	6	90/90	A/A, HM
Condensate Storage and Dump	2	44	13.6	0/190	A/A, HM
Catalytic Oxidizer	1	32	1.5	190/190	HM
Interchange Circulation Assembly	1	20	1.3	50/50	A/A
Avionics Fan Assembly	2	85.8	3.6	1340/1340	A/A, HM
Avionics Heat Exchanger	2	68.6	1.5	--	A/A, HM
Fire and Smoke Detection	2	12	0.2	20/20	A/A, HM

ECLS SUBSYSTEM CHARACTERISTICS - INITIAL CONFIGURATION (continued)

Equipment	No. Req'd	Weight (lb)	Volume (cu ft)	Power Ave/Peak (watts)	Location
Ducts	Set	287	20	--	A/A, HM
Water Tanks	16	640	67.2	--	A/A
Water Distribution	Set	7	0.1	--	A/A, HM, LM
Water Monitoring	1	20	0.5	50/50	HM
Water Pump Package	2	64	2.5	480/480	A/A
Cold Plates	15	87	4.5	--	A/A, HM
Lines and Disconnects	Set	16	0.5	--	A/A, HM

The major expendable requirement for the initial configuration is shown in Table 4.5.2.1.2-2. The data given for the first 90 days are the expendables which must be placed onboard to sustain the crew for 90 days before a logistics module is launched. A lower atmosphere leakage rate (1 lb/day) and small repressurization volume (habitability module) is used for this condition.

Normal resupply is based on 180 days of expendables normally used onboard. The 30-day contingency supply includes metabolic oxygen and atmosphere leakage (2 lbs/day). EVA requirements are not included in the table.

Totals are also given in the table for (1) onboard contingency including repressurization gas, (2) normal resupply and (3) normal return to earth of waste water, multifiltration cartridges and charcoal. The values in the table show that normal return is slightly lower than resupply because gases used and not returned are greater than metabolic water generated by the crew.

The first 90 days' atmospheric stores will require six nitrogen tanks and 12 oxygen tanks, 18 total tanks, which will be located on the exterior of the Airlock/Adapter. During normal operation, contingency and repressurization gases will require eight nitrogen tanks and five oxygen tanks for 13 total number. Therefore, five tanks can be removed after the first 90 days and used in the Logistics Module or 18 tanks can be retained as additional contingency. Some tank recharging or replacement will be necessary and cross manifolding can allow change in the ratio of nitrogen/oxygen tanks. Extreme care is required, however, to preclude the safety hazard of nitrogen entering the oxygen supply potentially causing inadequate oxygen in the atmosphere.

Water requirements for the first 90 days will be stored in 13 tanks located in the Airlock/Adapter interior. Three empty tanks will also be provided for storage of earth return waste water. The tanks will be removable for return to earth for sterilization and reuse in the Logistics Module.

During normal operation, four water tanks will contain the contingency water in the Airlock/Adapter and 24 tanks located in the Logistics Module will supply/return normal use water.

Table 4.5.2.1.2-2

MAJOR ECLSS EXPENDABLE REQUIREMENTS

Expendable	Weight (lb) First 90 days	Weight (lb) Normal Operation	Volume (cu ft) First 90 days	Volume (cu ft) Normal Operation
Repressurization Oxygen	53	117	3.8	8.4
Repressurization Nitrogen	163	358	13.6	29.8
30-day Contingency Oxygen	173	180	12.4	12.9
30-day Contingency Nitrogen	44	67	3.7	5.6
Metabolic and Leakage Oxygen	518	1080	37.2	77.7
Leakage Nitrogen	133	400	11.1	33.3
30-day Contingency Water	531	531	8.5	8.5
Normal Use Water	1592	3184	25.5	50.9
Odor Control Charcoal Resupply	70	140	1.8	2.6
(Waste Water Return)	1876	3751	30.0	60.0
Total Contingency Onboard	997	1276	42.6	65.6
Total Normal Resupply	2313	4804	75.6	164.5
Total Normal Return	1946	3891	31.8	62.6

NOTES: 1) Normal operation includes 180-day resupply.
2) Tanks and store provisions not included.

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4.5.2.1.3 Remaining Issues - The ECLS subsystem design presented in the paragraphs above can reliably and safely provide support of the operations envisaged for the MSP. However, there are several issues remaining that merit further attention and these will be discussed in this paragraph.

<u>No Dump Requirement</u> - The current baseline for the MSP uses a solid amine CO_2 control system which dumps about 2.1 lbs/man-day of CO_2 overboard. This is a dipolar molecule and concern exists that this effluent could interfere with some experiment operations.

There are several practical design and operational solutions to this dumping of CO_2. First, an expendable material, such as LiOH, could be used which chemically absorbs the CO_2 to be later returned to earth. This is identical to the Orbiter/Spacelab concept. The main drawback to this approach is due to the large resupply/return expendables required amounting to about 1300 lbs launch and about 1600 lbs return for each resupply period. Also LiOH has been determined to be considerably more costly. Detailed trade data for LiOH and solid amine CO_2 control concepts are given in Paragraph 4.5.2.3.2.

If the no CO_2 dumping times are relatively short, LiOH can be used to adsorb the CO_2 only during the no-dump period with the solid amine being used during other times. Since the baseline design has LiOH for emergency use, the only impact of its use is the need for resupplying the LiOH cartridges amounting to about 14 lbs/day.

CO_2 dumping can be avoided for short durations by not operating the CO_2 removal systems and letting the CO_2 accumulate in the cabin. As an example, if the CO_2 control units were shut down, it would take about 15 hours for the CO_2 level to rise from the nominal control level of [illegible] mmHg to the maximum level of 7.6 mmHg.

Use of a completely closed oxygen system or operating the Bosch concept would also eliminate CO_2 dump, however, this [illegible] approach is considerably more costly, complex and would increase schedule [illegible].

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Based on the options and considerations discussed above, combined use of CO_2 buildup in the cabin plus short-term use of LiOH are the planned methods of avoiding CO_2 dump during sensitive experiment operation. As more specific experiment data becomes available, further analysis will be necessary to determine adequacy of this approach.

Initial 90-day Expendable Storage

The current MSP is designed to operate for the first 90 days without a logistics module. This requires storage of 90 days' expendables plus contingencies onboard the initial operational configuration consisting of an Habitability Module and an Airlock/Adapter. As discussed in Paragraph 4.5.2.1.2 above, this requirement results in waste water being stored onboard the MSP thereby complicating earth return and tank sterilization. The solution currently planned is to make the tanks physically removable for earth return. Additionally, the number and ratio of gaseous oxygen and nitrogen tanks required onboard initially is not the same as required for later operation thereby requiring reconfiguration or inefficient use of the tanks. Further study is needed to determine if the Logistics Module should be introduced earlier in the program.

4.5.2.2 Existing Hardware

Table 4.5.2.2-1 indicates the applicability of existing hardware for the Basic Manned Platform. The first six items in the table represent the basic Spacelab Atmosphere Revitalization System (ARS). Installation and much of the air ducting will be identical to Spacelab in Habitability Module and Payload Modules. Reconfiguration of the ARS will be necessary for the Airlock/Adapter because of the smaller diameter of the primary structure.

The LiOH/Temperature Control Valve package will normally contain charcoal cartridges for odor control when used in the MSP. During emergency mode of operation the charcoal will be removed and LiOH installed for emergency CO_2 control. These LiOH cartridges are identical to those used in the Spacelab and Orbiter.

Most of the Spacelab Atmosphere Storage and Control Section will be used in the MSP, however, the smaller nitrogen tank will be replaced by a larger

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Table 4.5.2.2-1

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EXISTING HARDWARE APPLICABILITY FOR BASIC MSP

Existing Item	Spacelab	Orbiter
Condensing Heat Exchanger	✓	
Fan Separators	✓	
Cabin Fan Package	✓	
Avionics Fan Package	✓	
Avionics Heat Exchanger	✓	
LiOH/Temperature Control Valve Package	✓	
Oxygen/Nitrogen Control Panel	✓	
Cabin Pressure Relief Assembly	✓	
Experiment Vent Assembly	✓	
Water Pump Package		✓
Potable/Wastewater Tanks		✓
N_2 Tanks		✓
O_2 Tanks		✓
Miscellaneous Valves, Sensors, Etc.	✓	✓

Orbiter tank. This is necessary because of the much higher storage requirements in the MSP. The Orbiter gaseous oxygen tank is also used.

Both Spacelab and Orbiter water pump packages were considered for the MSP, however, the Orbiter design appears more applicable because of its high pressure drop and flow capability. A water flow requirement of about 590 lbs/hr are anticipated for MSP which is higher than the 500 lb/hr capability of the Spacelab but well within the capability of Orbiter. Also, pressure drop requirements are expected to be higher than Spacelab but well within Orbiter capability. The Orbiter unit, however, appears to be somewhat overdesigned resulting in a relatively high power of 240 watts compared with 66 watts for Spacelab. Orbiter pump modifications for lower pressure drop and rate is a candidate as a power reduction measure.

4.5.2.3 Supporting Trades and Analyses

This paragraph presents the trades and analyses which were performed leading to the selection of the recommended ECLSS design.

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4.5.2.3.1 Trade of Carbon Dioxide Removal Concept - Current methods of CO_2 removal on Spacelab and Orbiter use lithium hydroxide (LiOH) to chemically absorb CO_2. Expendable LiOH requirements for seven-day Shuttle missions are reasonable, less than 100 lbs for a four-man crew. However, when extended to MSP conditions, the extended duration results in much larger quantities amounting to over 1000 lbs for 90 days' resupply. Therefore, regenerative concepts are attractive for MSP to reduce this large resupply. The trade reported on in this paragraph trades LiOH CO_2 control versus regenerative concepts including solid amine water desorbed (SAWD), molecular sieve and electrochemical depolarizer concentrator (EDC).

The regenerable solid amine system offers significant advantages for the initial MSP compared to the Spacelab baseline LiOH system. The solid amine includes two three-man packages capable of supporting a six-man crew. The only expendable is .12 lb/day of H_2O dumped as saturated CO_2 (14.5 lb H_2O in 120 days).

The Spacelab LiOH system was used for comparison to the regenerable solid amine. The non-regenerable LiOH chemical is consumed at the rate of 1.1 lb LiOH/lb CO_2. The LiOH expendable was sized for three-man continuous removal. The initial LiOH weight requires a 30-day contingency period (+300 lb penalty compared to SAWD). The weight penalty increases to 2000 lb at 120 days (see Figure 4.5.2.3.1-1). Return weight is shown because of its impact on the landing cargo weight limitation of the Orbiter. The LiOH is converted into the heavier Li_2CO_3 compound and therefore returns 25% heavier than at launch. The 30-day contingency stays in orbit.

Volume trade curves would be similar to the weight curves. LiOH requires 78 ft^3 more volume for a 120-day period. LiOH return volume is the same as at launch minus the 30-day contingency (17.2 ft^3).

Molecular sieves, HS-C type solid amine and electromechemical regenerable CO_2 removal concepts were considered and rejected in favor of the steam desorbed solid amine concept. The molecular sieves, configured for the future growth requirement of water and CO_2 save, require high temperatures and excessive power for regeneration. The HS-C type solid amine cannot be grown to have CO_2

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Figure 4.5.2.3.1-1

HAMILTON STANDARD

REGENERABLE CO_2 REMOVAL ADVANTAGE FOR BASIC MSP

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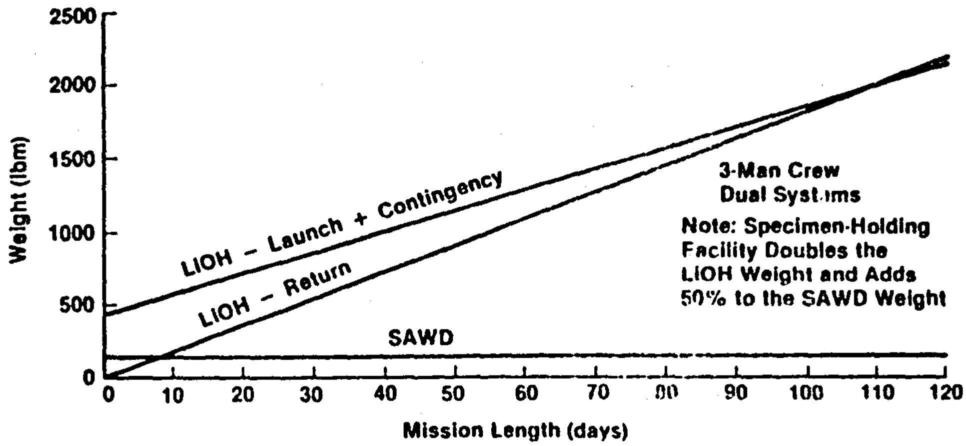

save capability and discharges valuable water when it is desorbing its CO_2 to vacuum. The electrochemical system would require additional oxygen supplies and otherwise unneeded hydrogen supplies since electrolysis which would nromally supply the gases is not required until the final growth step for the MSP ECLS system. For the above reasons and in trade studies the steam desorbed solid system has been shown to be safer, to have lower system weight and volume impacts and uses less system power, it was selected for the MSP.

4.5.2.3.2 Parametric Solid Amine CO_2 Control Study - This paragraph presents the detailed results of a study to develop subsystem data for variable crew size.

<u>Introduction</u>

The solid amine, water desorbed (SAWD) system is recommended for all growth steps of the Manned Space Platform (MSP) including the initial MSP. The SAWD concept uses a commercially available ion exchange resin, IRA-45, to selectively remove CO_2 from the cabin atmosphere and either dump the CO_2 overboard or deliver the CO_2 to a CO_2 reduction subsystem. The SAWD system is being specifically developed for a solar cell powered space station and should not be confused with the HS-C solid amine which was specifically developed for the fuel cell powered Shuttle Orbiter. The HS-C amine cannot selectively concentrate CO_2 and is, therefore, not applicable to space station.

In the following sections, the SAWD system is described, recommendations are justified and the parametric trade data is provided.

System Description

The SAWD system for MSP is shown schematically in Figure 4.5.2.3.2-1. The solid amine bed is the major component in the system. It holds the IRA-45 granular amine material.

Airflow during adsorption is provided by a fan and controlled by three air valves. Two valves are either open or closed while the third is used to modulate canister flow by venting a portion of the air around the canister.

Figure 4.5.2.3.2-1

MSP-SAWD

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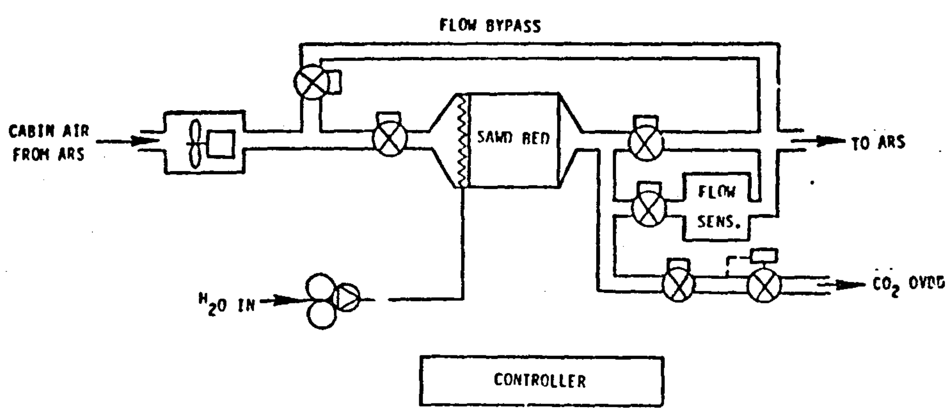

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During desorption, the two large canister valves close and the flow sensor loop is opened. Water is pumped to the integral bed steam generator which converts the water to superheated steam. The steam wave pushes residu. l ... out of the bed at a low flow rate as the steam moves through the bed. As the steam reaches the end of the bed, a high purity (99%) CO_2 wave evolves off the bed, sharply increasing the flow rate. The flow sensor picks up the increase in flow and switches the CO_2 flow either overboard or to a CO_2 reduction subsystem. The bed desorption temperature is controlled by a back pressure regulator in the CO_2 outlet. The desorption process is controlled to the saturation temperature of steam at the regulated pressure which is baselined at 212°F and 14.7 psia.

A controller/sequencer is used to time and sequence the various valving, pumping and fan flow activities. The controller will also assist in fault detection and automatic shutdown sequencing.

Conclusions/Recommendations

The weight, power and volume for a complete MSP CO_2 removal system (two SAWD subsystems) is shown in Figure 4.5.2.3.2-2. The weight and volume curves are the total for two SAWD subsystems. The power curve is the total for one subsystem adsorbing plus the other subsystem desorbing. The subsystems are synchronized so that the high power desorption cycles do not coincide, thus averaging the power draw and heat rejection demands.

Table 4.5.2.3.2-1 presents a list of the trade data used.

Fixed Weight: The fixed weight total is for two SAWD subsystems, one installed in the Airlock/Adapter and the other in the Habitat.

Logistics Weight: Logistics weight defines the amount of water lost overboard during CO_2 dumping that must be replaced at the logistics resupply period. The quantity equals 14.4 pounds for a four-man crew every 90 days.

Fixed Volume : This is the volume of the two installed subsystems.

Logistics Volume" This is the volume of water that must be resupplied and equals 0.25 ft^3 every 90 days for a four-man crew.

Power : The power is divided into two sections, normal power and full crew power.

Figure 4.5.2.3.2-2

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MSP-SAWD

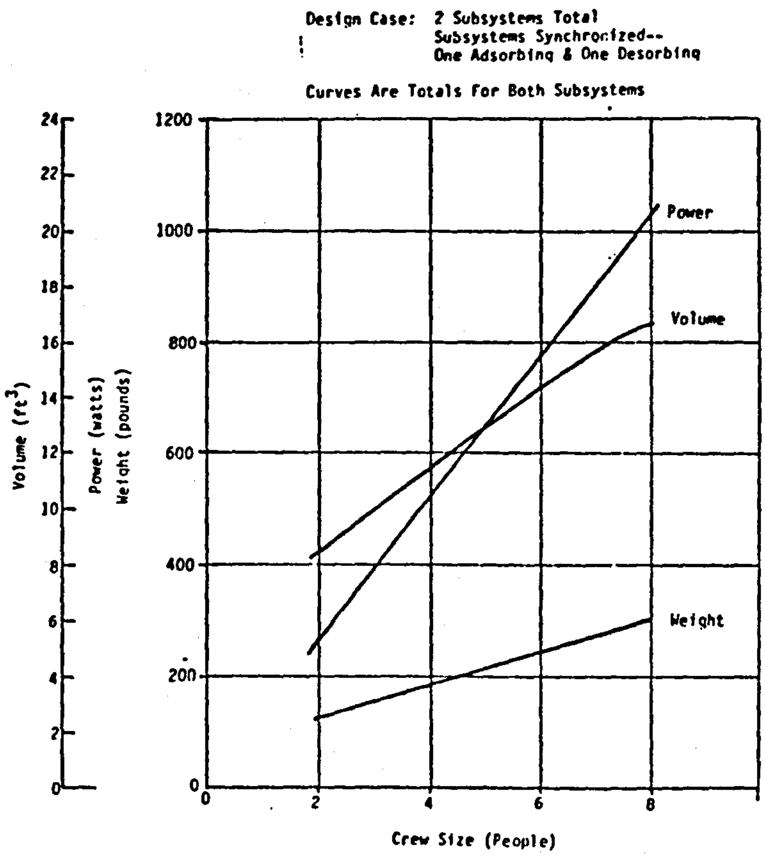

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Table 4.5.2.3.2-1

SAWD TRADE DATA

Parameter	Units	Crew Size 2	Crew Size 4	Crew Size 6	Crew Size 8
Fixed Weight					
SAWD Subsystem	lb	62	91	122	150
Total MSP	lb	124	182	244	300
Logistic Weight					
Total MSP (H_2O Dumped w/CO_2)	lb/day	.08	.16	.24	.32
Fixed Volume					
SAWD Subsystem	ft^3	4.2	5.7	7.2	8.3
Total MSP	ft^3	8.4	11.4	14.4	16.6
Logistic Volume					
H_2O Dumped w/CO_2	ft^3/day	.0013	.0026	.0039	.0051
Power - Normal					
Adsorb/Subsystem	watts	45	80	120	155
Desorb/Subsystem	watts	215	430	650	860
Total MSP	watts	260	510	770	1015
Power - Full Crew					
Max-Desorb	watts	370	740	1120	1480
Cooling Load - Average					
Adsorb/Subsystem	Btu/hr (1)	710	1390	2100	2800
Desorb/Subsystem	Btu/hr (2)	145	255	370	475
Total MSP	Btu/hr	855	1645	2470	3275
Reliability					
MTBF	hr	16500	16500	16500	16500

(1) 80% Latent
20% Sensible

(2) 100% Sensible

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Normally the crew load is split between the two subsystems, each handling half the crew at a PCO_2 level of 3.8 mmHg. The two subsystems are synchronized so that one desorbs while the other adsorbs. As such, the total power at any time is the total of two powers.

During a condition where all the crew is isolated in either module, a full crew operating mode is used. The adsorb and desorb cycles are shortened to handle the increased load. The desorb power draw increases to the maximum value given in the table. During adsorb the total power drops back to the normal adsorb value.

Cooling/Heating Loads: Only cooling loads are presented in the table because heating of the steam is reflected in the desorb power numbers. If a 250°F temperature source heat transfer loop becomes available on MSP, the desorb power can be converted to a heating load.

The cooling loads are divided into two categories; adsorb and desorb. The majority of cooling is required during adsorb because the latent heat, added to the bed during desorb, is transferred to the cabin coolant loop during the adsorb cycle. Durin desorb, the heat loss is considerably lower being comprised of the sensible loss from the warm bed and steam controller. On MSP, these loads appear cyclically on the separate coolant loops but because of the synchronization of the cycles, the total MSP load is relatively constant, being the sum of absorb plus desorb loads.

Reliability/Life Data: The Mean-Time-Between-Failures (MTBF) for each SAWD subsystem is calculated to be 16,500 hours.

Certain components are considered life limited. These are the rotating pump and fan. Replacement is recommended every 2-1/2 years. However, because of maintainable designs and availability of spares, an on condition maintenance philosophy should be considered for MSP. This would allow these components to operate until failure, whereby the second subsystem and large habitable volume would allow sufficient time to isolate, schedule and replace the failed component.

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Trace Contaminant Performance: The ability of the solid amine chemical, used in SAWD, to concentrate and desorb trace contaminants has not been tested in enough detail to forecast performance. Testing of a similar, but vaccum desorbed, amine showed excellent trace contaminant performance.

Testing by the French Navy showed the SAWD amine (IRA-45) would adsorb water soluble contaminants (ethanol and acetone) at high concentrations (1000 ppm) and desorb them during steaming. It also determined that CO_2 performance was not affected by typical airborne contaminants.

4.5.2.3.2A Condensate Water Recovery

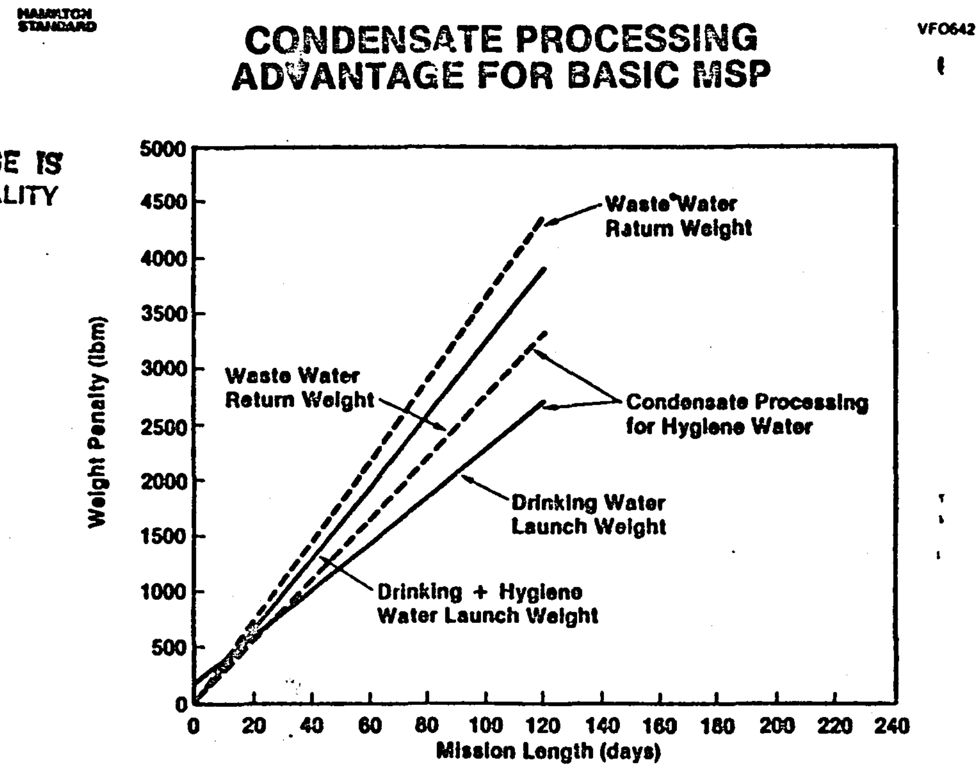
Because of MSP groundrules of minimum initial cost and program risk, full water recovery is not indicated. However, condensate water can be processed and used for hygiene water use with a relatively simple multifiltration process. This trade compared resupplying water versus onboard condensate processing for hygiene water use.

Figure 4.5.2.3.2A-1 shows the relative weight advantage of using processed condensate water rather than potable water for hygiene. The weights shown reflect water plus tankage which must be launched and returned to earth. The return weights for either option are higher than their respective launch weights because of the additional water obtained from wet food and the water produced during the metabolism of the food.

For the option using condensate water processing for hygiene, the launch weight includes the weight of multifiltration hardware. Since this is a one time only penalty, the line would be lowered by 200 pounds for subsequent launches. It is anticipated that a cost break-even point for incorporating multifiltration water processing will be between 90 and 180 days. Until a cost per pound (or a cost per cubic foot) is determined a precise cost trade cannot be determined. It should be noted that a volume difference of 27 ft^3 exists between the two concepts for a 120-day requirement (112 ft^3 with no condensate processing vs 85 ft^3 with condensate processing).

The use of multifiltration for condensate processing provides a first step, in-orbit evaluation, of water recycling with minimal risk.

Figure 4.5.2.3.2A-1



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The multifiltration design being considered here is similar to the unit which would be required to clean up processed water in a full water recovery system being considered for the growth MSP. Therefore, the condensate processing unit would be incorporated in later more advanced concepts for a no-throwaway approach.

4.5.2.3.3 Atmosphere Humidity and Temperature Control Trade

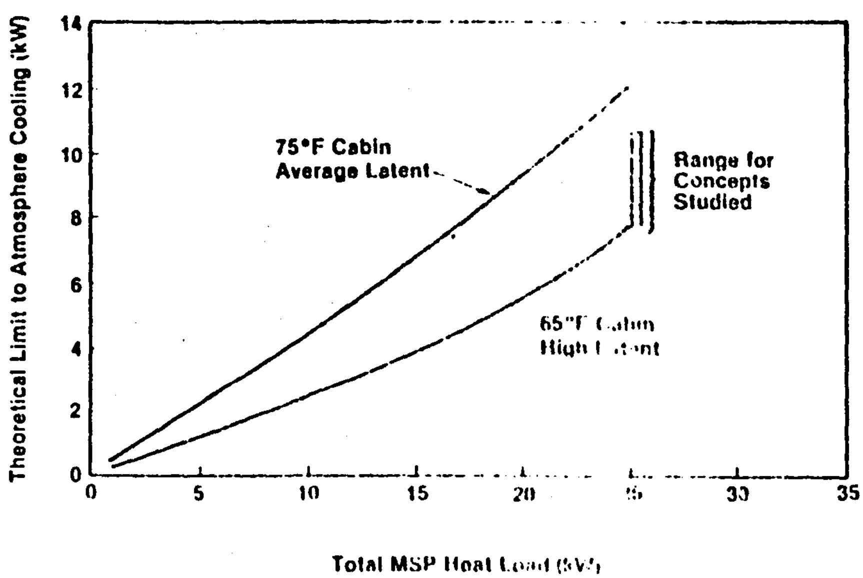
This trade compares several methods of integrating the condensing heat exchanger with the water thermal control loops. The Spacelab unit, which is a prime component, uses a single condensing heat exchanger to both control humidity and cabin air temperature. An alternate is to use separate heat exchangers; a condensing heat exchanger with low air flow for humidity control and a higher air flow unit for controlling cabin air temperature. The advantage of the alternate approach is that it allows a centralized unit to provide humidity control for several modules thereby reducing the amount of more complex condensate handling units. Therefore, the functions of humidity and temperature control are accomplished by units optimized for each separate function. On the other hand, the single unit Spacelab approach requires condensate collection in each module.

An important consideration in this trade is the maximum cabin cooling which can be obtained. The theoretical limit can be seen in Figure 4.5.2.3.3-1 and this occurs when the air outlet temperature equals the cooling water inlet temperature. This condition could occur in a condensing heat exchanger with unlimited capacity. The figure shows the result for cabin temperature of 65 and 75°F and two levels of latent loads. Also shown on the figure is the range of concepts studied, all corresponding to a 75°F cabin temperature. As can be seen, the theoretical limit could be approached reasonably close which means that based on MSP cooling water and air conditions, higher capacity heat exchangers could not greatly increase atmosphere cooling.

Low load capability refers to the minimum atmosphere cooling load required to maintain cabin temperature and humidity. If the load falls below this minimum,

Figure 4.5.2.3.3-1

THEORETICAL LIMITS FOR ATMOSPHERE COOLING



the cabin temperature will be reduced or additional heat must be added. Low load capability is an important aspect of the design to obtain high levels of operational flexibility.

Capability to grow refers to the ability to maintain atmosphere humidity and temperature in all modules in the growth versions. In most cases there will be less cooling water available to each module and therefore the humidity and temperature control function will be more critical. This consideration is addressed for each candidate in the paragraphs below.

Options for Humidity and Temperature Control

In the paragraphs below, five different heat exchanger arrangement options will be described and their basic characteristics will be compared. Three of the options consist of the Spacelab single unit approach and two options consist of separate heat exchangers for humidity and temperature control. The performance is based on a 75°F cabin temperature, a water supply of 43°F and latent loads corresponding to a three-man crew split equally in the three modules plus a specimen latent load in the payload module.

Series Arrangement of Dual-function Heat Exchangers

Figure 4.5.2.3.3-2 depicts this option which arranges Spacelab condensing heat exchangers in series in each cooling water loop. This circulating water from the Power System interface flows first through the heat exchangers so that the coldest fluid can be used for the humidity control function. The amount of sensible cooling obtained in the first condenser must be limited to about 1.74 kW so that a water supply temperature of 53°F or lower is available to the second heat exchanger in the loop. This is necessary to ensure humidity control in the second module. A total cooling capacity of 5.31 kW (0.66 kW latent) is obtained in the Airlock/Adapter and Payload Module. The water loop servicing the habitability module will provide 4.05 kW (0.23 kW latent) of cooling. Other heat loads are located downstream of the condensing heat exchangers.

The performance shown in Figure 4.5.2.3.3-2 is based on the highest anticipated water flow rate of 592 lb/hr/loop. This flow will be lower if the MSP is not using the entire 25 kW electrical power from the Power System. If some of the

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Figure 4.5.2.3.3-2

SERIES ARRANGEMENT OF DUAL-FUNCTION HEAT EXCHANGERS

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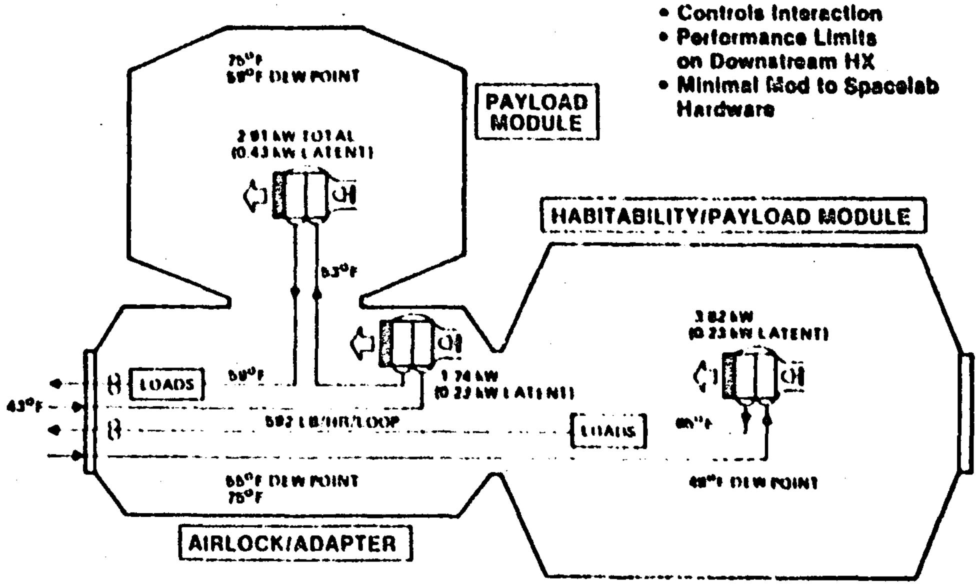

cooling must be dedicated to payloads attached directly to the Power System, less water flow will be available to the MSP. The impact of reduced water flow on humidity and temperature control is shown in Figure 4.5.2.3.3-3. The data shows that a water loop flow of at least 300 lb/hr is necessary to control humidity to 60°F dew point temperature in the second module. At that flow, however, no cooling would be available in the first heat exchanger so higher water flow is necessary.

During growth, an additional Airlock/Adapter, habitation module and payload modules are fitted on the initial configuration to increase capability. In this option, atmosphere humidity and temperature control would be provided in these growth modules by placing additional condensing heat exchangers in series with the condenser servicing the initial Habitation Module. Since three or more heat exchangers would then be located in one water loop, the flow would be increased in that loop and decreased in the first loop so that water loop flow and heat loads are balanced. Another alternate would place approximately equal number of heat exchangers in each loop.

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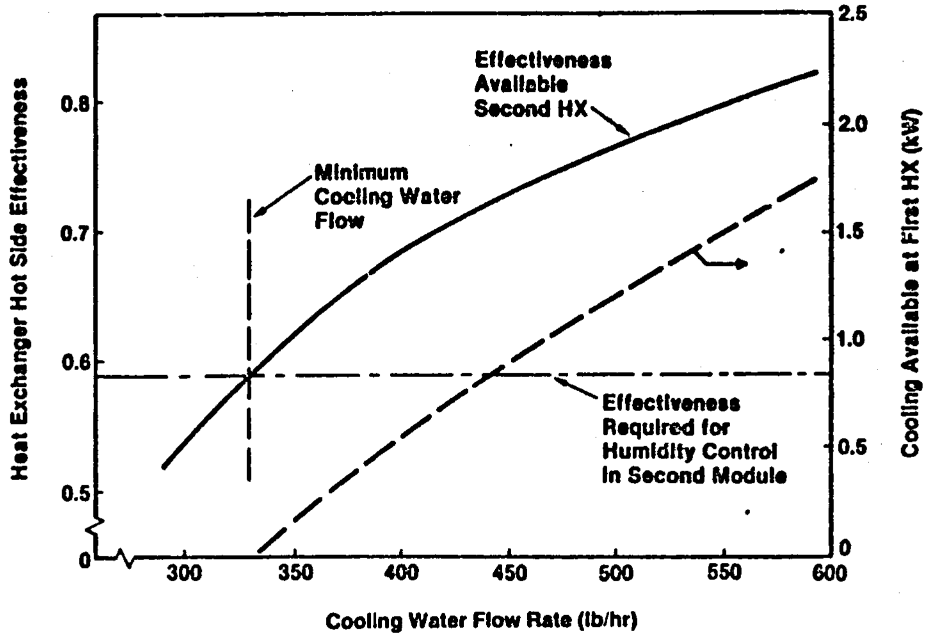
Figure 4.5.2.3.3-3

PERFORMANCE OF SERIES ARRANGEMENT OF DUAL-FUNCTION HEAT EXCHANGERS



Parallel Arrangement of Dual-function Heat Exchangers

This arrangement, shown in Figure 4.5.2.3.3-4, is similar to the concept discussed above except the heat exchangers are located in parallel. The advantage of this concept is that 43°F fluid is available to each condensing heat exchanger for control of humidity. Likewise, about the same amount of cabin air cooling can be provided at each heat exchanger, so the system is well balanced. The main disadvantage can be seen from Figure 4.5.2.3.3-5 which gives performance of varying numbers of heat exchangers. When the number approaches four condensers, the cabin dew point starts to exceed the 60°F maximum allowable. This is caused by insufficient cooling water flow rate to each condenser to lower the air temperature to about 58°F as required for allowable humidity level. The figure also shows the total sensible cooling available and amount for each heat exchanger. The range of performance shown is due to range of anticipated cabin air temperature and latent loads.

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Figure 4.5.2.3.3-4

PARALLEL ARRANGEMENT OF DUAL-FUNCTION HEAT EXCHANGERS

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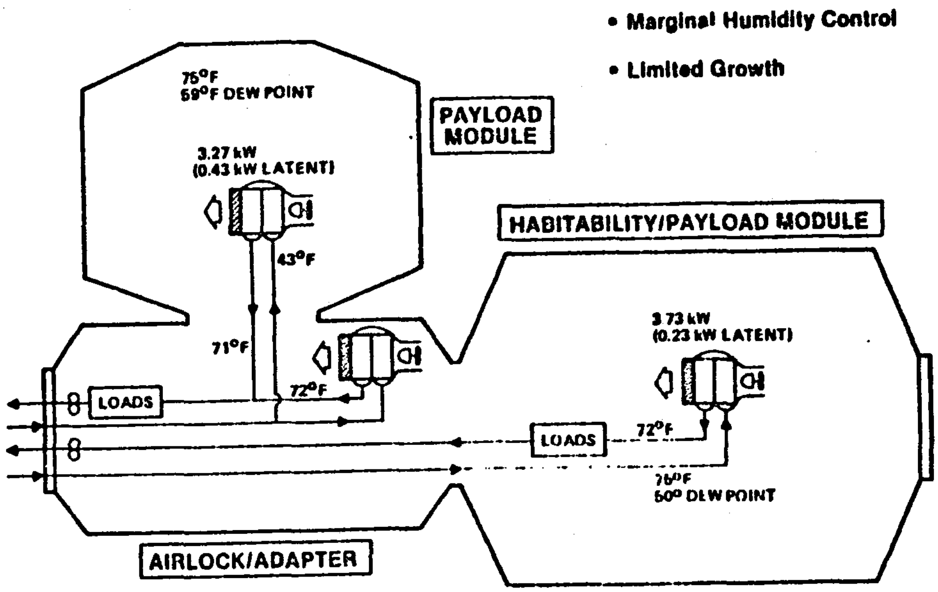

Figure 4.5.2.3.3-5

PERFORMANCE FOR PARALLEL ARRANGEMENT OF DUAL-FUNCTION HEAT EXCHANGERS

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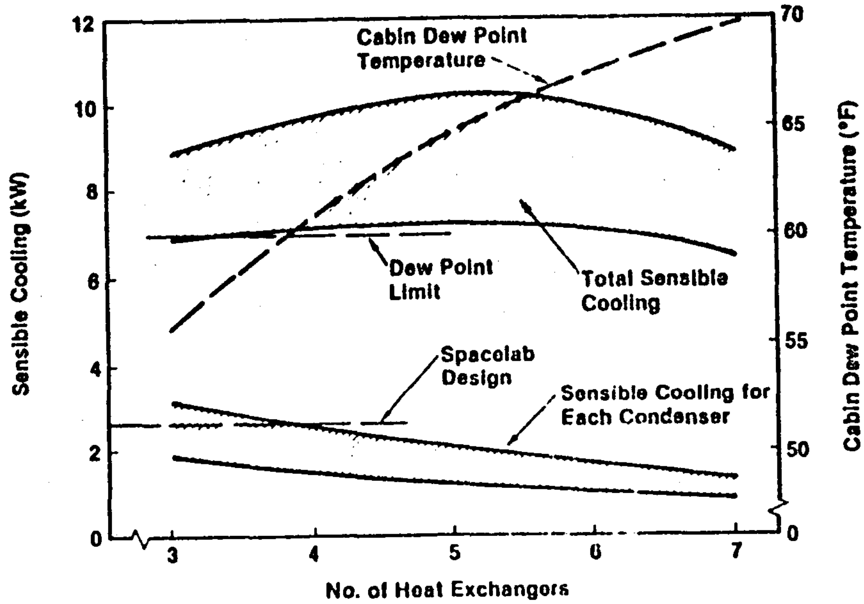
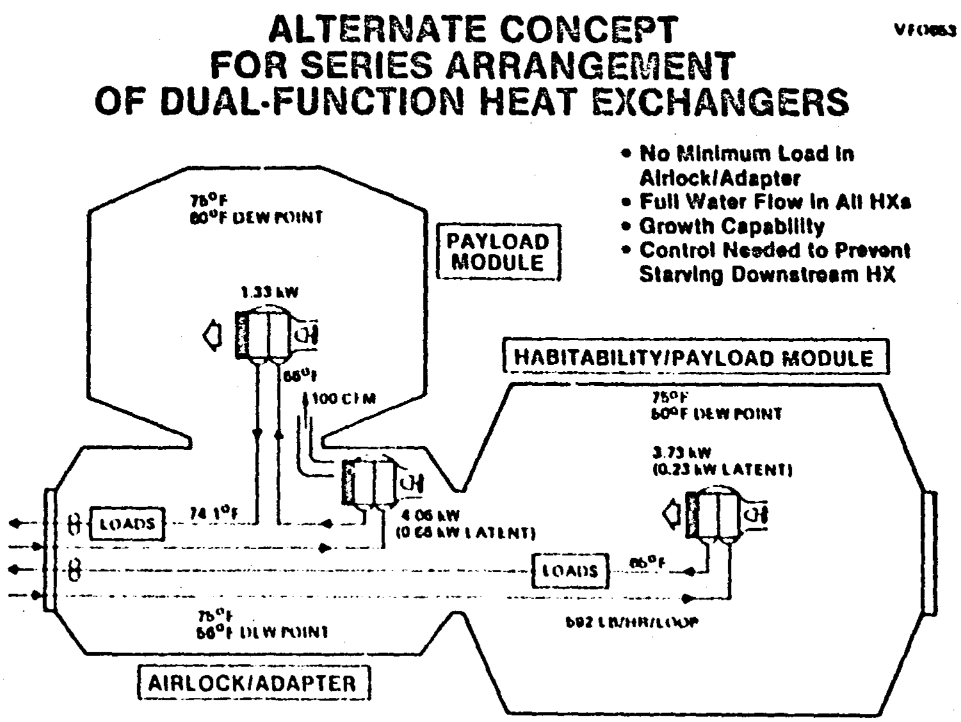


Growth is severely limited for this option because only about four modules at most can be accommodated based on the Spacelab approach of a single dual-function heat exchanger located in the module. One possible solution to the problem is to limit the total number of heat exchangers to three or four and cool the remaining module by interchanging air between modules. However, this approach also has performance limitations and fan powers would be large for the relatively large interchange flows required.

<u>Alternate Concept- Series Arrangement of Dual-function Heat Exchangers with Interchange</u>

Figure 4.5.2.3.3-6 shows an alternate to the concept shown in Figure 4.5.2.3.3-2. This concept is identical to that shown before but interchange is provided between modules. This allows more cooling to be extracted from the first heat exchanger in the loop, thereby avoiding the restriction of 53°F maximum allowable water temperature to the downstream condenser. Figure 4.5.2.3.3-6 shows conditions for maximum cooling in the upstream heat exchanger, 4.06 kW cooling available. Adequate interchange is provided to keep the dew point in the Payload Module below 60°F.

Figure 4.5.2.3.3-6



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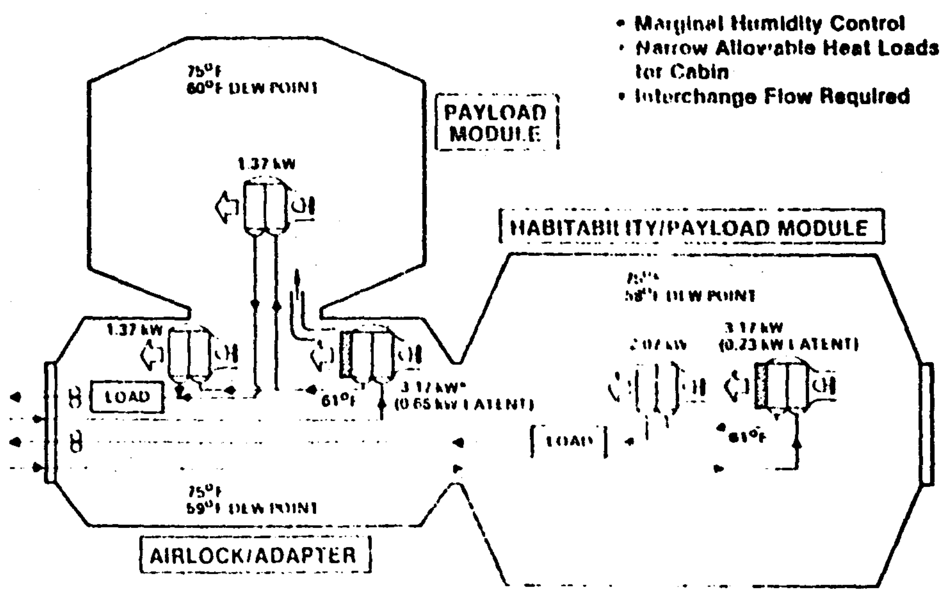
Separate Function Heat Exchangers - No Water Loop Temperature Control

Figure 4.5.2.3.3-7 depicts this concept which locates a humidity control condenser in each separate compartment and a non-condensing sensible air cooling heat exchanger in each module. The condenser receives the coldest, 43°F, fluid from the Power System interface as required to maintain a low outlet dew point temperature. The outlet temperature from the condenser is 61°F to ensure no condensation in downstream heat exchangers at or below the maximum cabin dew point of 60°F.

These conditions result in a total cooling of 3.17 kW in the condensers or a sensible cooling load of 2.51 kW in the Airlock/Adapter and 2.94 kW in the Habitability Module. The maximum sensible cooling which can be obtained with Spacelab equipment is also shown in the figure. The condenser load cannot fall below the 3.17 kW total in order to prevent condensation in the sensible cooling heat exchangers. If inadequate cabin heat loads are present, a cabin air heater must be provided or a temperature control is necessary in the water loop. This approach is discussed in the next paragraph.

Figure 4.5.2.3.3-7

SEPARATE-FUNCTION HEAT EXCHANGERS WITH NO COOLING WATER TEMPERATURE CONTROL



*A PORTION OF THIS COOLING AVAILABLE FOR PAYLOAD MODULE

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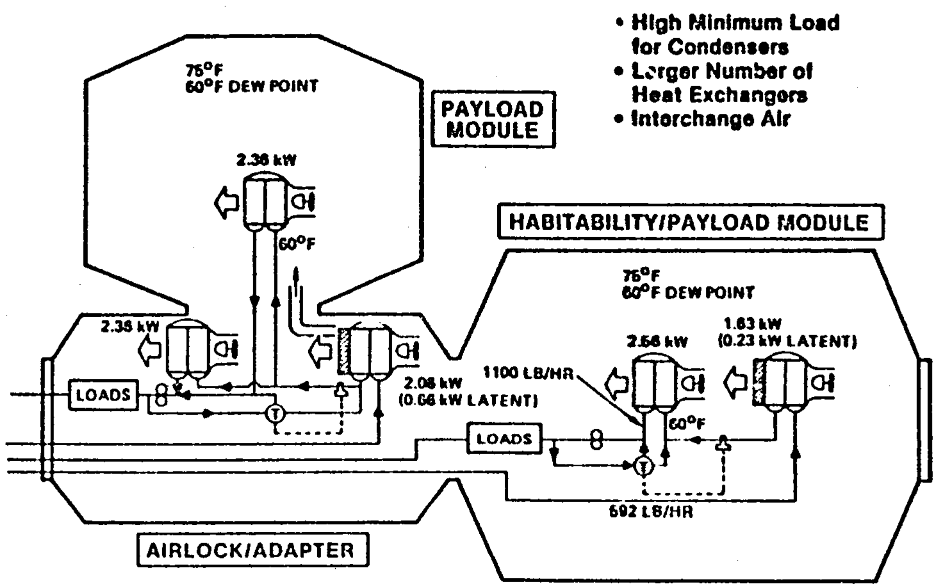
Separate Function Heat Exchangers - Water Loop Temperature Control

The condenser heat exchangers in the option discussed above had relatively large minimum heat load requirements in order to avoid condensation in the sensible cooling heat exchangers. In the option presented in this paragraph, a temperature control is placed in the water loop to add water loop pump outlet fluid to the water flowing to the sensible heat exchangers (see Figure 4.5.2.3.3-8). There are two major advantages to this approach. First the minimum load in the two condensers can be reduced from 6.34 to 3.69 kW. This corresponds to a reduction in minimum sensible cooling load from 5.45 to 2.8 kW (nearly 50%). The second advantage is that the performance of the sensible heat exchangers is improved because larger water flow rates occur in the units. This raises the total sensible cooling available from a single Spacelab heat exchanger from 1.37 to 2.36 kW (based on two units on the loop). The total sensible cooling for the initial MSP is reduced very slightly because the condensers are providing less cooling with this option incorporating water loop temperature control.

Figure 4.5.2.3.3-8

PERFORMANCE FOR SEPARATE-FUNCTION HEAT EXCHANGERS WITH COOLING WATER TEMPERATURE CONTROL



Two major disadvantages of this option is due to the complexity of the control valve and the higher pump power associated with the increased water flow in part of the water loop. The control valve requirements are to maintain a constant water flow (592 lb/hr for 25 kW MSP) to the Power System interface and then split the pump bypass flow to the inlet and outlet of the sensible heat exchanger. This split is established by the valve control logic to maintain a 60°F temperature to the sensible heat exchanger inlet.

Comparison of Concepts

Table 4.5.2.3.3-1 compares the concepts based on the criteria discussed in the preceding paragraphs. Distinguishing data is enclosed in a box.

The results show that the dual-function units have the advantage of having no minimum load and represent small penalties. Existing Spacelab unit can be used with no changes. The parallel arranged units have poor growth capability with the addition of more modules because the concept is very water

Table 4.5.2.3.3-1

SUMMARY OF TRADE STUDY RESULTS ATMOSPHERE HUMIDITY AND TEMPERATURE CONTROL

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Criteria	Dual-Function HXs: Series	Dual-Function HXs: Parallel	Separate-Function HXs: No Temperature Control	Separate-Function HXs: Temperature Control
Sensible Cooling				
Per Compartment (kW)	$\boxed{1.51}$-3.59	2.84-3.13	1.37-4.96	3.06-3.96
Total (kW)	$\boxed{7.59}$	9.11	11.22	10.08
Minimum Load (kW)	0	0	$\boxed{3.17}$	1.63(1)
Cabin Dew Point Temp (°F)	48-59	53-57	58-60	60
Penalties	Small	Small	2 Add HXs	$\boxed{\text{High}}$
Growth	$\boxed{\text{Single Module Limits}}$	$\boxed{\text{Limited}}$	Medium	Medium
Water Flow Sensitivity	Sensitive	$\boxed{\text{Very}}$	Medium	Minimal

(1) Function of Water Pump Design Flow

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flow sensitive. The series arrangement has limited cooling performance per compartment and for the entire MSP.

The main disadvantage of the separate-function heat exchanger approaches is that more heat exchangers are required. Also both of these concepts have a large minimum load requirement and is high (3.17 kW) when there is no water loop temperature control. The concept with temperature control requires a complex control and pump power will be high, perhaps double the other concepts.

The simpler concept using dual-function is adequate. Interchange air as depicted in Figure 4.5.2.3.3-6 can be used to improve performance by (1) increasing total sensible cooling from 7.59 to 8.23 kW and (2) increase minimum sensible cooling load in the Airlock/Adapter from 1.51 to 3.59 kW.

Growth Concept for Atmosphere Humidity and Temperature Control

Figure 4.5.2.3.3-9 shows how the recommended concept can grow with the addition of modules. In the case shown, an Airlock/Adapter and experiment

Figure 4.5.2.3.3-9

GROWTH CONCEPT FOR ATMOSPHERE HUMIDITY AND TEMPERATURE

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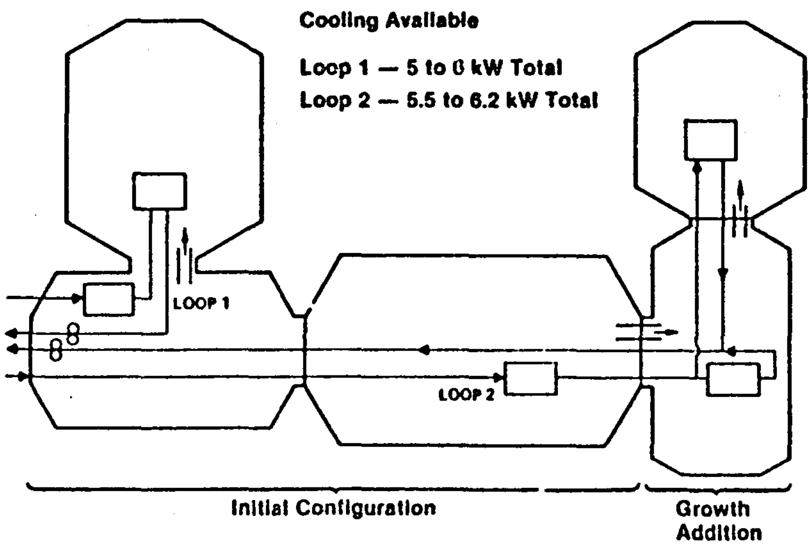

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module are added at the end of the Habitability Module. The dual purpose heat exchangers of the growth modules are added in series with the unit in the Habitability Module. Air interchange is provided between the modules. The total cooling available in this configuration is shown on the figure which can provide up to 12.2 kW total cooling for both loops. This value is higher than the maximum available in Figure 4.5.2.3.3-1 because a higher inlet temperature of 80°F was used to account for fan and under-floor heat loads.

Figure 4.5.2.3.3-9 shows interchange between Habitability Module and the growth Airlock/Adapter and between the growth Airlock/Adapter and the growth payload module. This will result in a slightly higher humidity level in the Airlock/Adapter compared with the Habitability Module and the growth Payload Module can be even higher. For cases of high Habitability Module heat loads, the humidity can be excessive in the growth Payload Module when high latent loads exist there. One solution to this problem is to run the interchange duct all the way between Habitability Module and growth Payload Module, however, fan power will increase. This design decision is contingent upon the detailed Payload Module design loads.

4.5.2.4 Degree of Oxygen and Water Recovery

The degree of oxygen and water recovery from waste products has a major system level impact because recovery concepts increase initial costs and program risk but reduce resupply needs. The savings in resupply can be shown with mass balances for various levels of closure as will be shown in this section.

As a point of departure, it should be noted that noe of the past manned programs have recovered oxygen or water. Considerable development effort has gone into recovery concepts, however, and many of these have reached a sufficiently advanced state so as to be considered for use in the timeframe of MSP.

Spacelab and Orbiter are relatively short duration missions and have an ample supply of fuel cell product water. Therefore, loop closure shows little benefit so open-loop concepts are used. An example of a mass balance for open loop is shown in Figure 4.5.2.4-1 which uses LiOH for CO_2 control and recovers no water or oxygen. The major expendables used by the four-man crew are

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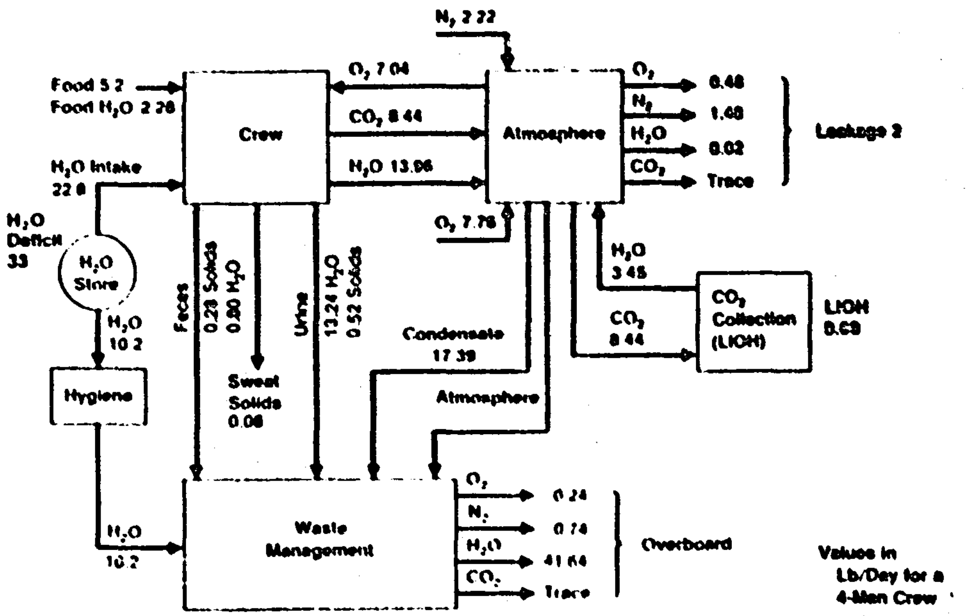
Figure 4.5.2.4-1

MASS BALANCE FOR INITIAL MSP ORBITER/SPACELAB SUBSYSTEMS



7.04 lb/day of oxygen, 33 lb/day of crew drinking and hygiene water and 78.48 lb/day of food. Also, about 9.69 lb/day (unpackaged) of LiOH is required for CO_2 control. Most of these expendables are also returned to earth in the form of CO_2 absorbed on LiOH; waste water and solids. Since return (landing) capability of the Orbiter is less than launch, this large return could be critical under some operating conditions.

Figure 4.5.2.4-2 is similar to the Spacelab/Orbiter concept except for the addition of condensate recovery and a regenerative CO_2 control unit. These additions are included because of early cost and weight advantages and they do not represent an appreciable increase in program risk.

This basic system concept as shown in Figure 4.5.2.4-2 represents a decrease in total expendables for a three-man crew about 14 lb/day not including packaging penalties. Earth return expendables have decreased by about 21 lb/day primarily due to reductions in CO_2, LiOH and water return.

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Figure 4.5.2.4-2

MSP ECLS BASIC SYSTEM

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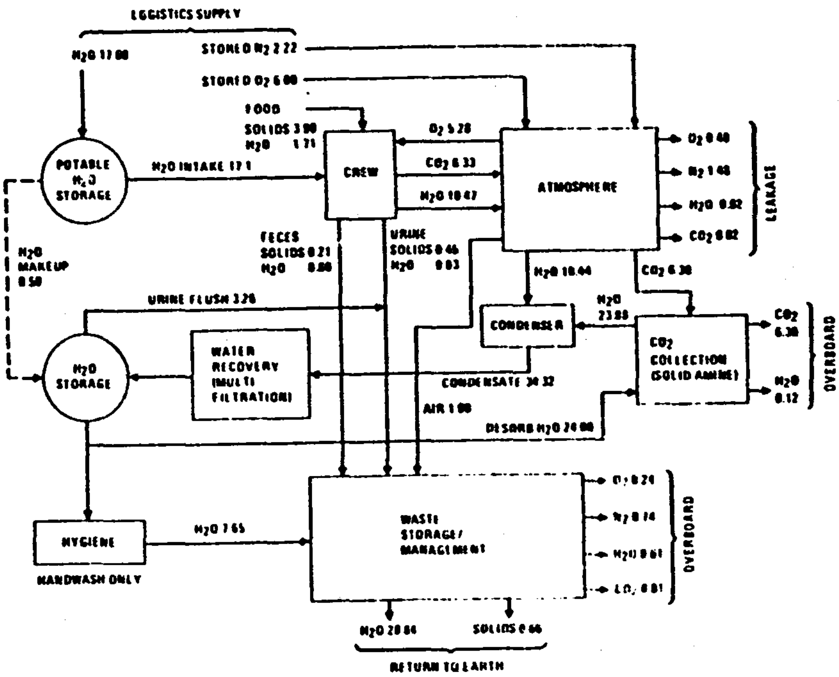

As MSP operations become more diverse, crew accommodations will increase and more use of EVA is anticipated. This is reflected in the mass balance for an "Intermediate System" as shown in Figure 4.5.2.4-3 where one shower per crewman every two days and limited clothes washing is provided. This increase in water use is accompanied by a water recovery concept which can recover wash water. Competing concepts for wash water recovery include Vapor Compression Distillation (VDC) and Thermoelectric Integrated Membrane Evaporation System (TIMES). Either of these concepts can be also used for urine water recovery and as indicated in Figure 4.5.2.4-2, a valve and line are provided to allow testing of the system with urine water supply. Verification of the process will allow later routine urine water processing.

No significant change occurs in expendable resupply/return between the Basic and Intermediate Systems. However, water use has increased by 53.25 lb/day.

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Figure 4.5.2.4-3

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MSP ECLS INTERMEDIATE SYSTEM

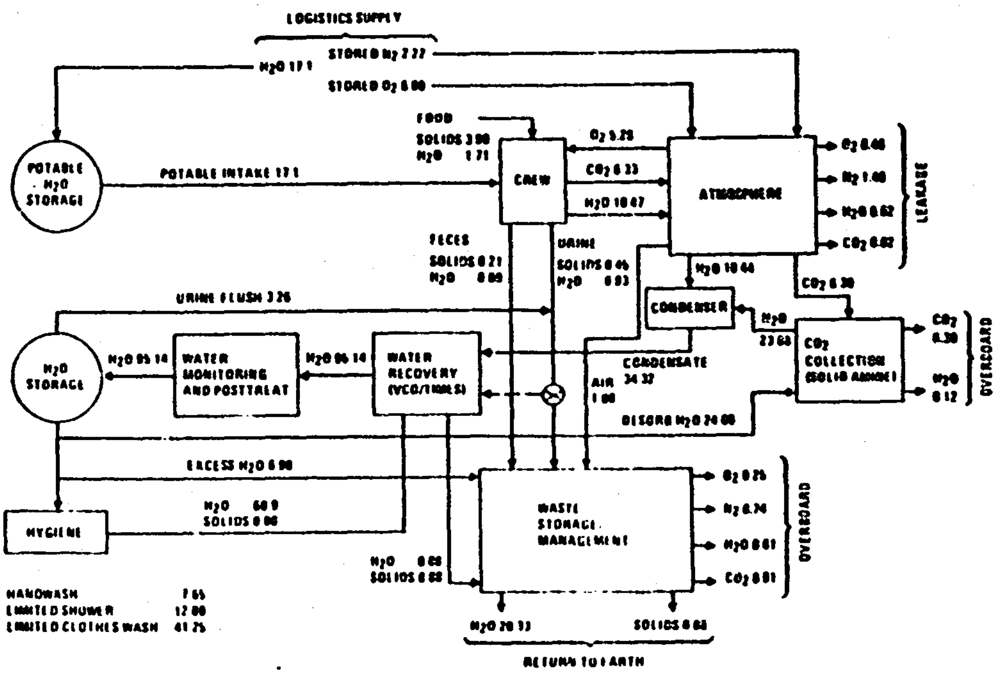

Figure 4.5.2.4-4 shows the "Growth System" where water is recovered from all sources except fecal water and partial oxygen recovery is provided with a Sabatier system. Hygiene water has been increased for better crew accommodation, one shower/man day, and increased clothes washing. Solid polymer water electrolysis produces oxygen for makeup and hydrogen for use in the Sabatier reactor.

Use of the Growth System concept will reduce expendable supply and return needs to very low levels; the main resupply items are food and nitrogen.

The groundrules of low intial cost and program risk and maximum use of existing hardware results in the recommendation of the Basic System for the initial MSP. The additions of a regenerative CO_2 control and condensate processing are sufficiently cost effective and low risk to merit their inclusion in the Basic System.

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Figure 4.5.2.4-4

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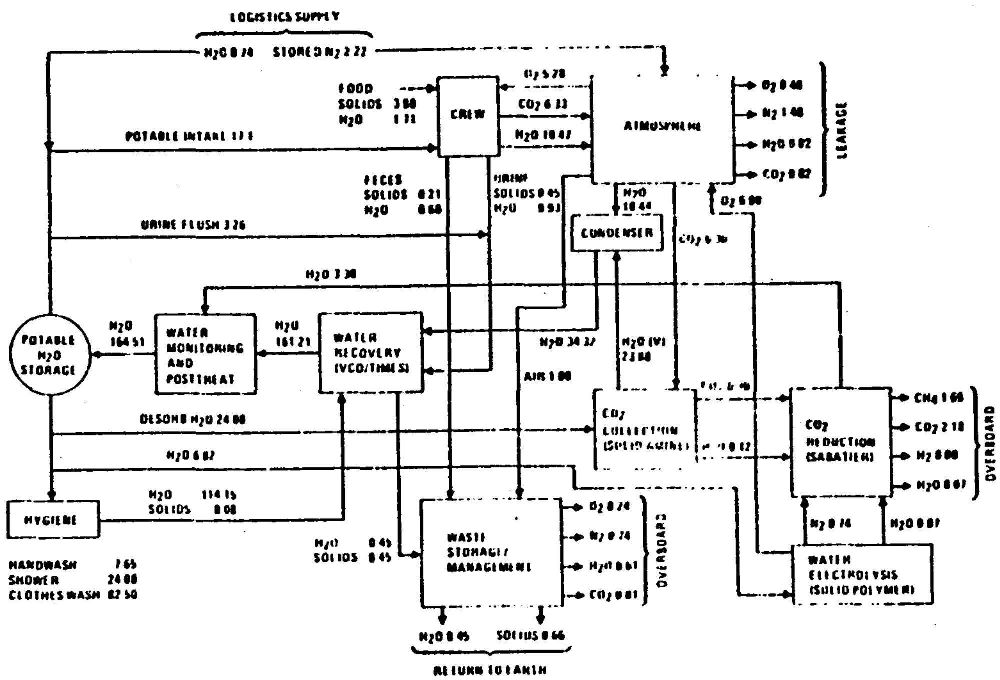
MSP ECLS GROWTH SYSTEM



As the program proceeds, the design can be upgraded first to the Intermediate System prior to adoption of the Growth System or growth may be directly to the Growth System in one step. The selected path would depend on the precise growth path of the MSP program.

4.5.2.5 Avionics Equipment Cooling Method

Equipment located within the habitable volume of the platform can be cooled by forced air circulation or by cold plate mounting. In the latter method, cooling water is circulated in the cold plate passages thereby providing for the equipment cooling. This trade compares the panalties involved in these two cooling methods in terms of weight, power and volume. Two levels of power density (heat per unit area) were considered.

Figure 4.5.2.5-1 shows the result of the trade for a Spacelab-type of design. Cold plating resulted in lower penalties in all cases, however, weight and volume advantages were small for low density applications. For high density applications, weight and volume penalties were two to four times less for

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Figure 4.5.2.5-1

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AIR COOLING VERSUS COLD PLATE COOLING

Consideration	Avionics Loop		Cold Plate	
	High Density (Per kW)	Low Density (Per ft^3)	High Density (Per kW)	Low Density (Per ft^3)
Weight (lb)	37	1.6	18	1.5
Power (W)	164	4.1	0.7	0.1
Volume (ft^3)	5.4	0.4	1.4	0.1

Other Considerations:

1. **Unique Designs for Cold Plating**
2. **Water-Loop Pressure Drop Considerations**
3. **Air-Cooled Avionics Run About 15 to 20°F Hotter**
4. **Fire Detection**

Conclusions:

Recommend Cold Plates Where Practical, Especially for High Power Density Applications

cold-plating. The greatest differences existed in power penalty which was over 200 times greater for high power density air cooled avionics. Additionally, because of the higher heat transfer coefficients, air-cooled equipment will operate 15 to 20°F hotter.

Although coldplating is strongly favored from a weight, power and volume standpoint, this approach requires special packaging designs which physically interface properly with the coldplate so most of the heat is conducted from the equipment to the coldplated side. This is nearly always a special space design which is different for ground or aircraft designs which rely on free or forced convetion cooling. Therefore, for new applications, a design for convection cooling usually impacts cost and schedule.

Coldplating does not necessarily eleiminate the need for air flow since some forced circulation is needed for efficient fire and smoke detection. This ensures that any smoke will be transported to a detector where it can be sensed.

As a result of the lower penalties, colplated cooling is recommended where cost and schedule impacts are not overriding. Coldplating is especially preferred for new designs of very high density designs.

4.5.3 Communications and Data Management Subsystem

The concept for the manned platform CDMS is based on the utilization and adaptation of existing Shuttle and Spacelab CDMS hardware. New hardware designs or major design modifications are used only for (1) increased mission duration, (2) accommodation of the Space Platform (SP) interface or (3) implementation of functions unique to the Manned Space Platform (MSP). The requirement for increased mission duration (with respect to Shuttle/Spacelab) has been approached by revising the CDMS architecture to include additional units and by taking advantage of crew capability to troubleshoot and replace faulty units with units from an onboard spares stock.

The key features of the CDMS design concept are shown in Figure 4.5.3-1. Because the overall platform concept is an evolutionary one, an important

Figure 4.5.3-1

MSP CDMS FEATURES

- **Utilizes Developed Equipment**
- **Provides Flexible Crew Accommodation**
- **Accommodates SP and Orbiter Interfaces**
- **Exhibits Improved Reliability**
- **Accommodates Platform Growth**

feature of the CDMS is its capability to support this evolutionary growth with minimal on-orbit reconfiguration and integration.. This capability is enhanced through standardization of hardware and software interfaces and by placing emphasis on functional modularity in the hardware and software design.

Figure 4.5.3-2 shows the allocation of CDMS functions among the major elements of a full-up platform. This allocation is based on several key assumptions and driving system level characteristics:

1. All ground communications are via the Space Platform (and TDRSS).
2. In a Shuttle-tended mode, crew control will be exercised from the Orbiter aft flight deck, supplemented or backed up by the Airlock/Adapter.
3. In the free-flyer mode, the Habitat Module contains the primary control center, with a contingency capability provided in the Airlock/Adapter.

Figure 4.5.3-2

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CDMS FUNCTION ALLOCATION

Function	SPACE Platform	MANNED SPACE Platform				
		Airlock Adapter	Payload Module	Habitat	Logistics Module	Beam
Communications and Tracking						
Voice Intercom		X	X	X		
EVA		X				
Detached Vehicle		X(G)				
Ground (TDRSS)	X					
Data Handling						
Acquisition	X	X	X	X	X	X
Distribution	X	X	X	X	X	X
Processing	X	X(I)	X(P/L)	X		
Storage	X		X(P/L)	X(I)	X(Film)	
Display/Crew Input		X		X		
Closed-Circuit TV						
Cameras	X	X	X	X		X
Monitors				X		
C&W/Safing						
Annunciation		X	X	X	X	
Controls		X	X	X	X	
Processing				X(I)		
Timing						
Generation	X					
Distribution	X	X	X	X		X
Timing Displays		X		X		

(G) Growth (I) Initial

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The CDMS description that follows assumes an early free-flyer configuration consisting of an Airlock/Adapter, a Payload Module, a Habitat Module and a Logistics Module. CDMS for later modules added in configurations are extensions and/or replications of the basic CDMS.

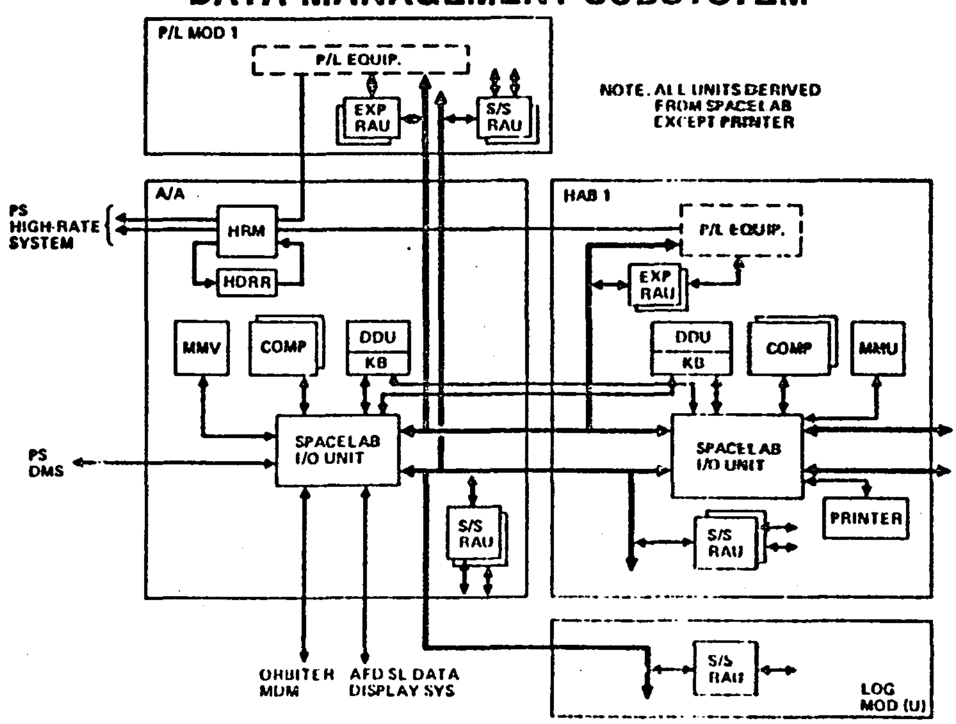
4.5.3.1 CDMS Definition

The CDMS definition has been divided into separate descriptions of the data management, voice communications, closed circuit television, timing and caution and warning (C&W) functions for convenience.

Data Management - The data management equipment concept is shown in Figure 4.5.3.1-1. This concept uses Spacelab data management hardware in a configuration that accommodates the primary and backup control center in the Habitat Module and the Airlock/Adapter. At the same time, the configuration includes more redundancy than the Spacelab configuration to improve the capability for longer missions.

Figure 4.5.3.1-1

PLATFORM (MSP)
DATA MANAGEMENT SUBSYSTEM



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The data management concept provides flexibility by allowing data display and control in either the Airlock/Adapter or the Habitat Module. Two Spacelab computers are provided in each module. At any given time, one of the four computers would operate as the subsystem computer, one would be available for experiment support and two would be backup units. Dual mass memory units are provided, one in each of the main modules.

An experiment data bus and a subsystem data bus are provided for data distribution throughout the platform. These operate in the same manner as the Spacelab data buses with Spacelab Remote Acquisition Units (RAUs) for data acquisition and command and timing distribution.

A high-rate data acquisition capability is included consisting of a Spacelab High Rate Multiplexer (HRM) and a High Data Rate Recorder (HDRR) from Spacelab. These units collect, multiplex and provide temporary storage for high-rate data and transmit the data across the SP interface to its high-rate communication channel.

Two areas in the data management equipment group require significant modification. The I/O units will require reconfiguration to allow the unit-to-unit data communication necessary for the expanded architecture and to support the flexibility needed. The system software will need to be revised to handle the hardware configurations. In both cases, however, it is expected that the basic Spacelab concept and many functional modules can be utilized.

The I/O units must be extremely flexible to support the data management concept. It is envisioned that either I/O unit can be assigned to drive either bus and can communicate with anyone of the four computers, either of the MMUs and either of the DDU/FBs. In addition, it may be expedient to provide some safehold mode control in the I/O units to handle computer failures.

Voice Communications - Figure 4.5.3.1-2 shows the MSP voice communication concept. Internal voice communications are straightforward and pose no particular development concern. Hardware from Shuttle and Spacelab can be used with very little, if any, modification.

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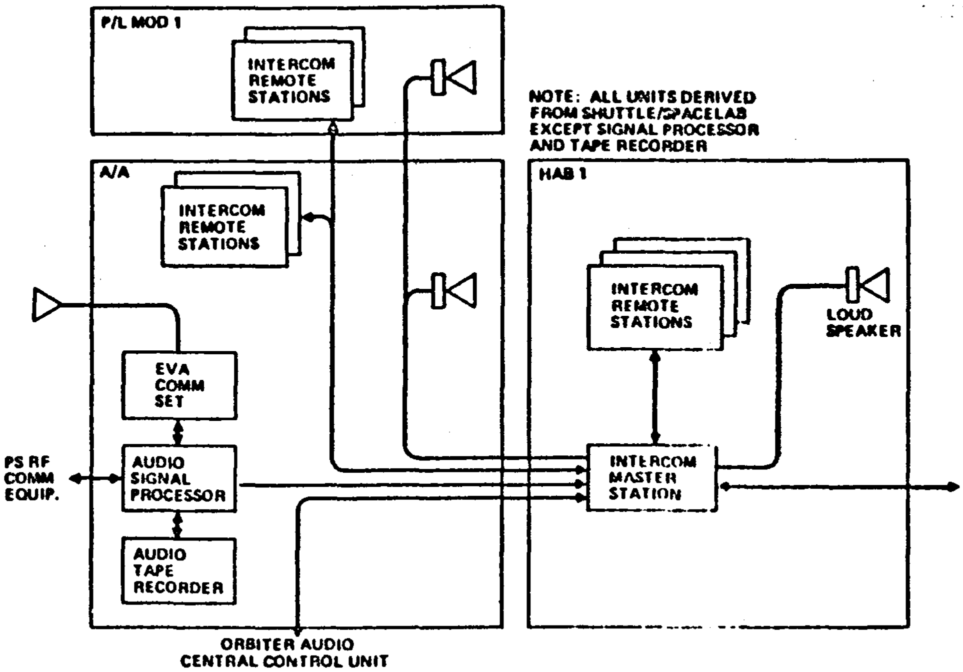
Figure 4.5.3.1-2

PLATFORM (MSP)
VOICE COMMUNICATION SUBSYSTEM



Voice communications to the ground are through the SP communications equipment. The audio signal processor in the Adapter/Airlock provides the A/D conversion (downlink) and D/A conversion (uplink) required to use the SP digital communication channels for voice. This is similar to the Shuttle voice communication system and poses no particular technical challenge. On Shuttle, a voice channel normally occupies 32 kbps of the digital channel capacity. It may be desirable to use less bandwidth for voice on a long-duration platform mission so that TDRSS capacity is used efficiently.

An EVA communications set is provided to allow crew personnel inside the platform to communicate with EVA crew. The EVA link can also be tied into the ground communications link. EVA communications equipment would be the Orbiter equipment to avoid new development and to assure compatibility with EVA equipment.

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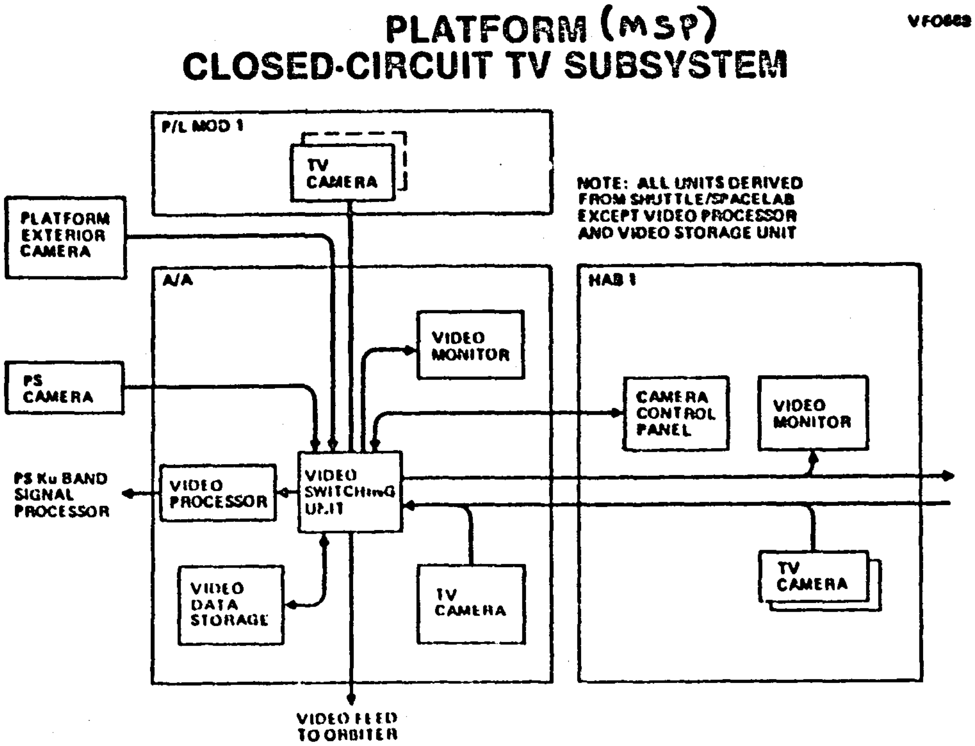
Closed Circuit Television - Figure 4.5.3.1-3 shows the MSP closed circuit television concept. The hardware for this subsystem is also straightforward and is available from Shuttle and Spacelab. To allow the picture signal to be sent to the ground via the Power System communication link, A/D conversion is required. This is provided in the Video Processor Unit. Digital transmission of commercial bandwidth television signals uses a large portion of the Ku-band downlink capacity. If the television downlink requirements result in excessive communication channel loading, several options are available, including TV data compression techniques and SP modifications to provide a non-digital FM mode for TV data transmission.

An uplink television capability has not been included in the concept because no clear requirement was established. If such a requirement is established in the future, a slow-scan television uplink can be implemented using the baseline reference PS uplink capability. However, that uplink capability (300 kbps) will not support a fast-scan TV uplink.

Figure 4.5.3.1-3

PLATFORM (MSP)
CLOSED-CIRCUIT TV SUBSYSTEM



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Timing - The MSP accepts timing signals from the Master Timing Unit in the SP or the Orbiter, distributes the signals to the payload equipment and platform subsystems and provides time displays for the crew. Time displays include Greenwich Mean Time (GMT) and Mission Elapsed Time (MET). This time data (in IRIG-B format) are distributed throughout the platform along with precision frequency signals. Controls to allow crew updating and resetting of GMT and MET will be provided. Figure 4.5.3.1-4 shows the platform timing distribution concept.

Caution and Warning - A caution and warning (C&W) capability is required to alert the crew to immediate or impending hazards. Associated with this capability is a safing capability to allow immediate remedial action for certain hazards. Figure 4.5.3.1-5 shows the design concept for providing this capability.

Figure 4.5.3.1-4

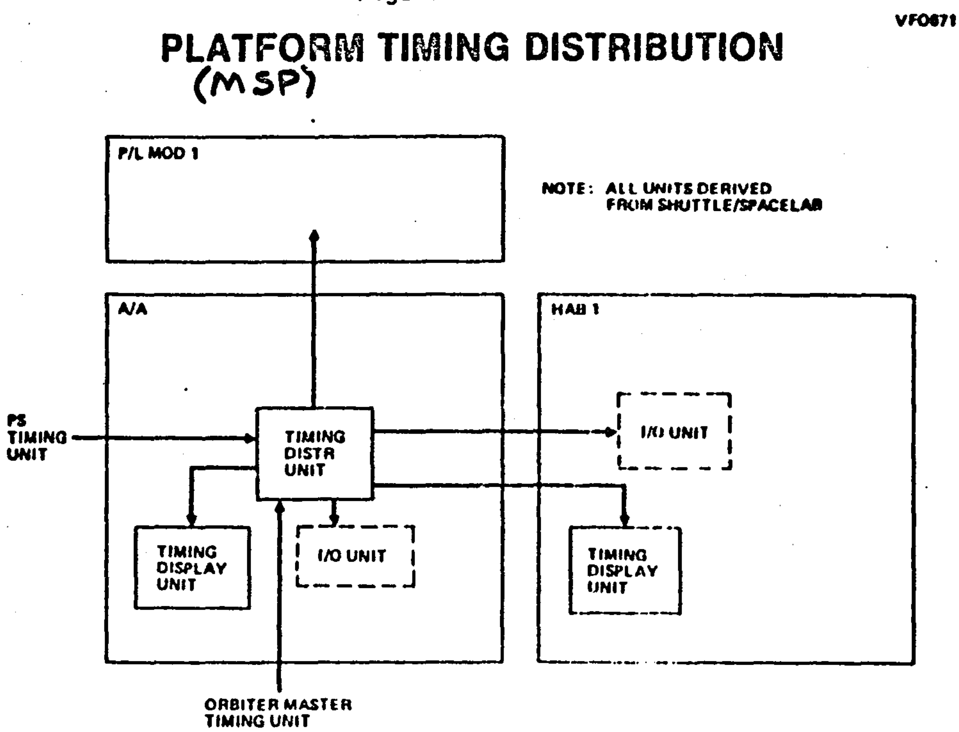

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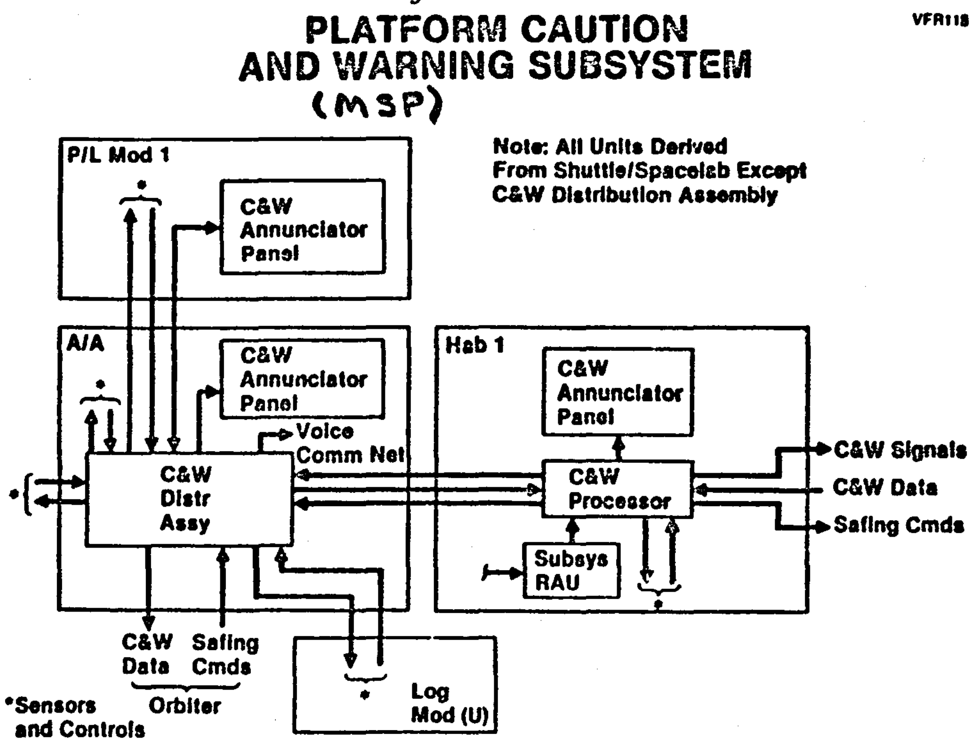
Figure 4.5.3.1-5

PLATFORM CAUTION AND WARNING SUBSYSTEM (MSP)



A key feature needed in a C&W subsystem is autonomy so that it retains its capability to detect, alert and safe hazards even though other subsystem elements (e.g., data processors) are not operating.

The C&W annunciator provides both visual and aural warnings of hazardous conditions. The aural warnings are also tied into the voice communication network. Safing controls are locatcd so that they would be readily accessible to one or more crewmen at any time.

Figure 4.5.3.1-6 summarizes the equipment items required to implement the CDMS design concept. The quantity of each item required per module is shown. Also shown is the pedigree of each hardware element.

The emphasis was placed on using existing equipment for several reasons:

1. This demonstrates a feasible approach to CDMS development and provides an indication of the low development risk.

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Figure 4.5.3.1-6

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CDMS EQUIPMENT SUMMARY

Unit	Pedigree	Utilization: Airlock/Adapter	P/L Mod	Hab Mod	Log Mod
I/O Unit	Spacelab	1		1	
DDU/KB	Spacelab	1		1	
Computer	Spacelab	2		2	
MMU	Spacelab	1		1	
Exp RAU	Spacelab		2	2	
Subsys RAU	Spacelab	2	2	2	1
HRM	Spacelab	1			
HDRR	Spacelab	1			
Printer	New			1	
TV Camera	Orbiter	1	1	2	
Video Monitor	Spacelab	1		1	
Video S/W Unit	Orbiter	1			
Video Processor	New	1			
Video Storage Unit	New	1			
Camera Control Pnl	Orbiter			1	
Intercom Master Sta	Spacelab			1	
Intercom Remote Sta	Spacelab	2	2	3	
Loudspeakers	Spacelab	1	1	2	
EVA Comm Set	Orbiter	1			
Audio Sig Proc	New	1			
Audio Recorder	New	1			
C&W Processor	Orbiter			1	
C&W Distr Unit	New	1			
C&W Annunciator Pnl	Orbiter	1	1	1	
Timing Distr Unit	Orbiter	1			
Timing Display Unit	Orbiter	1		1	

2. Supporting data (cost, power, volume, etc.) are readily available and are more credible than for undeveloped hardware.
3. Compatibility with the Spacelab module structural and thermal control concepts is assured by using Spacelab CDMS hardware.
4. Study resources sufficient to investigate and define new hardware were not available.

However, as the system-level platform concepts evolve, the CDMS approach should be reviewed and updated with particular attention paid to the potential benefits that might be available through the use of later technology. Electronics technology has advanced rapidly since Spacelab development was started and continues to do so. Important cost and performance benefits may be available by using new hardware based on current technology rather than existing Shuttle and Spacelab hardware.

Figure 4.5.3.1-7 shows a number of technical areas that are applicable to the CDMS where rapid technical advances have been and are taking place. These all offer potential cost or performance benefits for [illegible] platform.

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Figure 4.5.3.1-7

RAPID CDMS TECHNOLOGY GROWTH AREAS

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Technology Item	Potential Benefit
• Microprocessor Capability Growth	• Distributed Processing, Lower Software Development Costs, Enhanced Reliability
• Non-Volatile Storage	• Better Operational Flexibility, Enhanced Reliability, Lower Reprogramming Cost
• Display Technology Growth • Speech Recognition and Synthesis • Higher-Order Programming Languages	• Better Man-Machine Interface • Lower Development Costs
• Fiber Optic Data Transmission	• Wider Bandwidth, Less Weight, Lower Cost, Less EMI
• VHSIC and VLSIC	• Higher Package Density, Less Weight, Lower Cost Per Function
• Optical Storage	• Higher Bit Density

One of the most interesting areas of technical development is in microprocessor capability. Sixteen-bit microprocessors are readily available that have the speed and throughput equivalent to minicomputers and small main-frames of several years ago. The hardware cost of such microprocessors is almost trivial. This capability provides the opportunity for a distributed data processing system on the platform, where each subsystem provides its own data processing capability rather than all subsystems relying on a common central capability. A distributed data processing approach may provide several important potential advantages such as lower software development costs, simplified system integration and graceful failure modes.

Figure 4.5.3.1-7 shows potential benefits of other technical advances that could enhance a platform CDMS based on new hardware designs.

A major concern for a CDMS based on Shuttle/Spacelab hardware and a major factor in any CDMS approach is the reliability goal for long mission durations. ESA studies of long-duration Spacelab missions have identified the CDMS as the least reliable subsystem. These studies have identified several ways that the CDMS reliability can be improved including (1) system reconfiguration for increased redundancy, (2) on-orbit unit placement and (3) reliability upgrades to the design and manufacture of existing hardware units. The first two of these three have been included in the platform CDMS concept. However, a quantitative reliability assessment has not been made and further reliability improvements may eventually be needed.

Figure 4.5.3.1-8 summarizes these two major concerns in the CDMS as open issues. Future platform definition studies should address these concerns in depth.

4.5.3.2 Existing CDMS Hardware

As discussed in previous paragraphs, the CDMS design concept is largely based on existing Shuttle and Spacelab CDMS equipment. This hardware will be developed and flight-proven and can be applied to a platform program with low development risk. Many ancillary costs, such as applications software development and crew training, will be lower if existing equipment from Shuttle and Spacelab can be used.

Figure 4.5.3.1-8

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CDMS OPEN ISSUES

CDMS Reliability

- **Additional Redundancy**
- **Onboard Spares, Fault Isolation, Repair**
- **Design/Manufacturing Upgrades**

Utilization of New Technology

- **Distributed Data Processing**
- **Improved IC and Computer Technology**
- **Fiber Optic Data Transmission**
- **Voice Recognition and Synthesis**
- **Display Technology**

Modifications required to the existing equipment designs are classified as major or minor as shown in Figure 4.5.3.2-1. The major modifications are in the data processing group where some modifications are needed to allow a system configuration suitable for long-duration missions. Minor modifications may be required to other units to adapt them to the platform system configuration and operational concept.

It is expected that all of the existing CDMS designs can be available for a late 1980s MSP development. However, the probable lack of a production base for many of the units will mean that a production capability will have to be re-established, alternate sources located for some components and design changes made to substitute for unavailable components.

4.5.3.3 Supporting Trades and Analyses

Several approaches are available for implementing the communications and data management requirements. A trade study was done to identify the most

Figure 4.5.3.2-1
MODIFICATIONS TO EXISTING CDMS EQUIPMENT DESIGNS

UNIT	DEGREE OF MODIFICATION	COMMENT
I/O UNIT	MAJOR	SUPPORTS REVISED SUBSYSTEM CONFIGURATION
DDU/KB	MINOR OR NONE	
COMPUTER	MAJOR	MEMORY EXPANSION
MMU	MINOR OR NONE	
EXP RAU	MINOR OR NONE	
SUBSYSTEM RAU	MINOR OR NONE	
HRM	MINOR OR NONE	
HDRR	MAJOR	UPGRADE FOR LONG MISSION
TV EQUIPMENT	MINOR OR NONE	
VOICE COMM EQUIP.	MINOR OR NONE	
C&W EQUIP.	MINOR OR NONE	
TIMING EQUIP.	MINOR OR NONE	

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appropriate CDMS design concept. The hardware approaches were categorized as shown in Figure 4.5.3.3-1. A number of the required functions of the CDMS are uniquely related to have man aboard. Examples of this are voice communication, data display and entry and caution and warning. Existing space-qualified hardware to provide these functions is available only from the Shuttle/Spacelab program. Qualified hardware to provide data acquisition, data distribution and data conditioning are available from other space programs. This hardware is represented in Figure 4.5.3.3-1 by the Standard Telemetry and Control Components (STACC) hardware and the Flexible Multiplexer-Demultiplexer (FMDM) hardware. Other existing hardware is available that performs the same general functions as STACC and FMDM but were not included.

Figure 4.5.3.3-2 lists the criteria that were used in the CDMS hardware selection. Emphasis was placed on the "Cost/Cost Risk," "Reliability" and Compatibility with Other Subsystems" factors. Spacelab equipment has an obvious advantage in that its use would assure compatibility with the Spacelab

Figure 4.5.3.3-1

CANDIDATE CDMS HARDWARE APPROACHES

- Spacelab/Shuttle Hardware
- STACC Hardware (Ref SP Approach)
- FMDM Hardware
- New-Technology Hardware

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Figure 4.5.3.3-2

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CDMS SELECTION CRITERIA

- **Requirement Accommodation**
- **Flexibility/Growth Capability**
- **Cost/Cost Risk**
- **Reliability**
- **Volume, Weight, and Power**
- **Compatibility With Other Subsystems**
- **Availability/Schedule Risk**

type module, with the environmental control subsystem and with the Orbiter interface. This equipment, however, does not provide proven, long-term reliability, since it has been developed for short-duration missions.

Other existing equipment, such as the STACC or FMDM hardware, provide better reliability but would require more extensive adaptation to meet the functional and interface requirements for a manned platform. The STACC hardware offers compatibility with the reference Space Platform data management equipment. This advantage, of course, depends on the ultimate PS CDMS configuration.

New hardware may end up being the most appropriate approach for an MSP. This approach offers several potential advantages such as better accommodation of functional requirements, improved reliability, lower software development costs and lower weight and volume. These potential advantages are difficult to evaluate at the present state of the program, however.

Figure 4.5.3.3-3 summarizes the advantages and disadvantages of the candidate CDMS hardware approaches for application to the manned platform. The maximum use of Shuttle and Spacelab hardware has been selected as the most appropriate approach at the current stage of program and system definition.

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Figure 4.5.3.3-3

COMPARISON OF CDMS HARDWARE APPROACHES

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Approach	Advantages	Disadvantages
Spacelab/Shuttle	• Developed • Low Risk • Compatible With Orbiter	• Reliability
STACC	• Developed • Qualified for Long Mission Life	• Capacity • Flexibility • No Man/Machine Interface
FMDM	• Potential for Distributed Processing • Flexible	• No Man/Machine Interface
New-Technology Hardware	• Potential Improvements in Performance, Reliability and Packaging	• Requires Development and Qualification • Cost Risk

SELECTED

The computer selection can be considered as a separate issue. In addition to the selection criteria previously discussed, the software development impacts associated with the choice of computers must be considered. Another important factor will be the eventual allocation of subsystem processing functions between the central data processor and the subsystem equipment. This distribution of processing functions warrants additional study.

Figure 4.5.3.3-4 compares the primary characteristics of most of the available space computers. The Spacelab computer has been selected for the current study design concept to provide a consistent CDMS approach. The subsystem reliability has been enhanced by using a 2 of 4 computer approach rather than the 2 of 3 that is used in Spacelab. Onboard spares can also be used for reliability improvement.

4.5.4 Electrical Power Subsystem

4.5.4.1 Subsystem Definition

The Electrical Power Subsystem (EPS) distributes regulated 30 VDC power from the Space Platform to all MSP subsystem and payload areas. Provision is also

Figure 4.5.3.3-4

SPACE COMPUTER STATUS

	MDAC 771	IBM NSSC-I	IBM NSSC-II	LITTON 4516 E	ITEK ATAC-16MS	ROCKWELL DDF-224	SPACELAB
STATUS	Developed	Flown	Developed	Qualified	Qualified	Flown	Qualified
WORD LENGTH (Bits)	16/32	18	16/32/64	16/32	16/32	24	8/16/32
FLOATING POINT	Yes	No	Yes	Yes	Yes	No	Yes
MEMORY SIZE	128Kx22	16Kx18	192Kx8	128Kx22	64Kx22	48Kx24	64Kx18
MEMORY TYPE	CMOS RAM	CORE	RAM	CMOS RAM	CMOS RAM	PLATED WIRE	CORE
SPEED-GIBSON MIX (Operations/Sec)	550K	NA	NA	539K (Fixed Pt)	375K (Fl. Pt)	350K (Fixed Pt)	350K (Fl. Pt)
HIGHER ORDER LANGUAGE	PASCAL FORTRAN	NONE	HAL-S FORTRAN	FORTRAN	HAL-S FORTRAN	NONE	FORTRAN
RELIABILITY (2 yr.)	NA	0.96	0.998	0.98	0.999	NA	LOW
WEIGHT (Lbs)	28	17.4	58	26	25	100	73
POWER (Watts)	79	31	130	77	63	100	370

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made for supplying and distributing 115/200 volt three-phase 400 Hz AC power and 30 VDC emergency power. The EPS functional requirements are summarized in Figure 4.5.4.1-1.

The allocation of EPS functions in the Space Platform, Airlock/Adapter and Habitability Module is shown in Figure 4.5.4.1-2. In addition, EPS functions are allocated to the logistics mosule, payload modules and payload pallets. The option for inverters in the A/A, as noted on the figure, is the subject of a trade in Paragraph 4.5.4.3. In the baseline subsystem configuration, two identical inverters are provided in both the A/A and the H/M. An option is also shown for batteries to back up the emergency power buses which are derived from the main power buses. Batteries are not included in the baseline configuration but the option is retained.

An overview of EPS design considerations can be given as follows:

- The design is Spacelab-derived to make maximum use of existing equipment.

Figure 4.5.4.1-1 VFM335N

ELECTRICAL POWER SUBSYSTEM FUNCTIONAL REQUIREMENTS

Supply 30-VDC Power to Orbiter Docking Port
Supply 30-VDC Power to MSP Subsytems and Experiments

- **Habitability Module**
- **Payload Modules**
- **Logistics Module**
- **Adapter/Airlock**

Retain Capability to Supply Additional Power For Growth Versions

- **30 VDC**
- **120 VDC**

Supply Emergency Power to Critical Loads

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Figure 4.5.4.1-2

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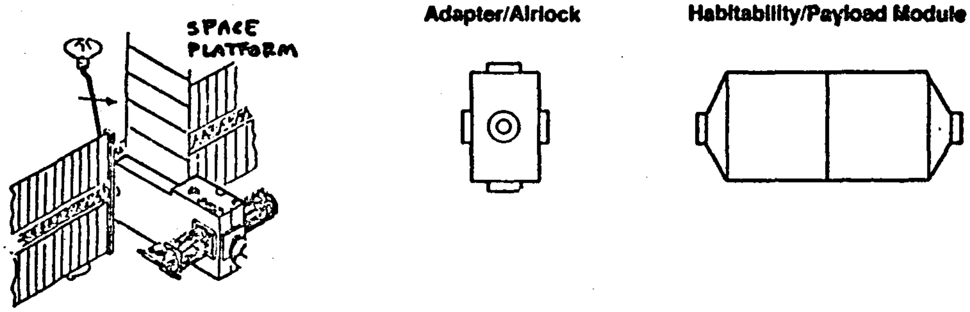
ALLOCATION OF EPS FUNCTIONS



Space Platform
- Power Source
- Batteries, Chargers, and Regulation
- Power Distribution and Control

Adapter/Airlock
- Power System Status and Monitoring
- Power Distribution and Control
- Inverters*
- Lighting
- Emergency Power Distributer

Habitability/Payload Module
- Power Distribution and Control
- Emergency Power Distribution (Batteries)*
- Lighting
- Inverters

*OPTIONS

- The impact due to extended duration on orbit is minimal. Mainly, it will consist of increasing fault isolation capability to the LRU level and improving access to equipment to perform maintenance.
- AC power is supplied by dedicated inverters at the platform module level.
- Power management is implemented by a combination of manual and remote automatic control.
- The charger/battery option for backing up the emergency power bus is retained.
- Growth capability at 30 VDC is provided. Alternate approaches using regulated high voltage (120 VDC) or possibly unregulated high voltage DC from the Power System interface are also considered.
- Grounding is referenced to the Space Platform single-point ground, switchable to the Orbiter single-point ground when the Orbiter interface is operational.

Average power requirements for the platform subsystems are given in Table 4.5.4.1-1. Total average power required for subsystems in the baseline

Table 4.5.4.1-1

SUBSYSTEM AVERAGE POWER IN WATTS

SUBSYSTEM	LOGISTICS MODULE DC(2)	LOGISTICS MODULE AC(3)	AIRLOCK/ADAPTER DC	AIRLOCK/ADAPTER AC	HABITABILITY MODULE DC	HABITABILITY MODULE AC	PAYLOAD (1) MODULES DC	PAYLOAD (1) MODULES AC	PAYLOAD PALLET DC	PAYLOAD PALLET AC
CDMS	19	--	1274	154	1232	154	179	--	106	--
ECLS	45	--	362	1502	416	1601	335	592	--	269
HAC	120	--	2	10	153	6	--	--	--	--
EPDS(4)	44	--	651	--	719	88	429	30	230	--
Subtotals	228	--	2326	1749	2483	1849	943	622	336	269
TOTAL DC & AC	228		4075		4332		1565		605	

(1) INITIAL VERSION - TOTAL FOR TWO LIFE SCIENCE PAYLOAD MODULES

(2) 28 VDC

(3) 115/200 VAC 400 Hz

(4) INCLUDES ALLOWANCES FOR SUBSYSTEM WIRING AND INVERTER LOSSES

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platform configuration is 11.4 kW. This is a substantial part of the 25 kW power available and consideration of means for reducing subsystem power consumption appears warranted.

Peak power demands range up to approximately 1.5 times average for subsystems in the Habitability Module. On the other hand, peak power demand for experiments on the earth-science pallet can go to nearly three times average power. Typically, power distribution systems are sized for 1.5 times average power. This correlates well with the subsystem requirements. In the case of the earth-science pallet, when the pallet subsystem loads are taken into account, the peak power demand is about 1.8 times average. This reduction, coupled with relatively low total power demand minimizes the effect on distribution design.

A block diagram sowing the basic elements of the EPS with provisions for growth and options is given in Figure 4.5.4.1-3. For the baseline configuration, the Habitability Module would be supplied as indicated by the solid

Figure 4.5.4.1-3

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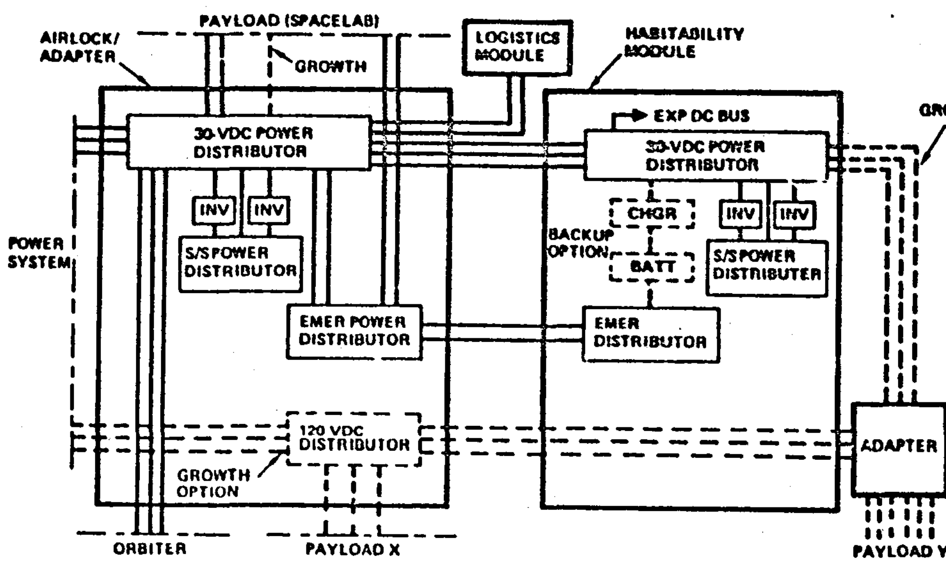
POWER DISTRIBUTION/OPTIONS



NOTE: FOR 120 VDC GROWTH OPTION, POWER CONDITIONING (NOT SHOWN) IS EITHER PLATFORM PROVIDED OR USER PROVIDED AS REQUIRED

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lines. When adapted for use in growth versions of the platform, the H/M would additionally provide bus extension power feedthrough capabilities as indicated by the dashed lines.

Power is distributed radially from a main 30 VDC distributor in the A/A to attached payloads, the H/M and logistics module and the Orbiter interface when active. Emergency power is distributed radially from the emergency distributor in the A/A to attached payloads and to the H/M. Subsystem DC and AC loads in the A/A and H/M are supplied from dedicated S/S power distributors. Experiment DC and AC loads are powered from dedicated experiment buses in the H/M and payload modules. The potential use of high voltage power distribution is identified for growth conditions where loss penalties for low voltage distribution may be unacceptable.

Figure 4.5.4.1-4 develops the distribution arrangement for the Habitability Module in more detail. This is essentially the Spacelab EPDS with the exception of the 30 VDC distributor and a third primary bus. Also, there is

Figure 4.5.4.1-4
HABITABILITY MODULE POWER DISTRIBUTION

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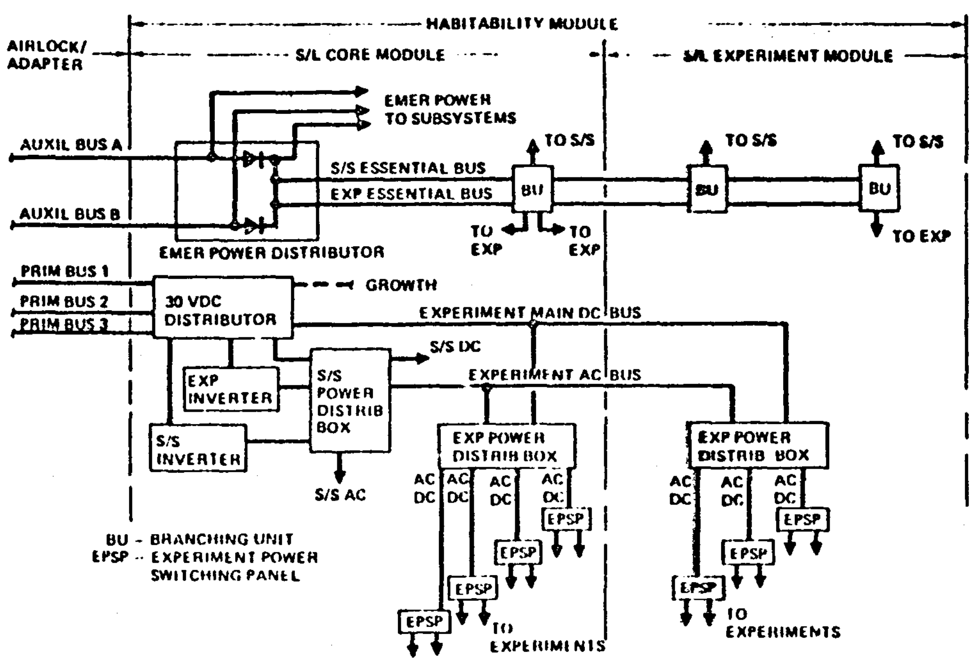

only one Experiment Power Distribution Box (EPDB) in the Experiment Module instead of two as provided for in Spacelab and only three Experiment Power Switching Panels (EPSP) instead of six. These reductions result from removal of equipment racks to make room for crew accommodations.

The 30 VDC distributor is the single package equivalent of the Power Control Box (PCB) and fuse box with the principal exception of the shunt regulator provided in the PCB for bus overvoltage protection. A shunt regulator is not required in the platform application because bux overvoltage protection is provided by the Power System. The distributor power throughput capability is increased over that of the PCB to facilitate bus extensions for platform growth. A similar distributor is used in the A/A as indicated in Figure 4.5.4.1-3.

The Habitability Module for the baseline configuration does not require feed-through capabilities and, therefore, could use a PCB and fuse box instead of a new distributor if this were more cost effective. Either approach would allow distributing the maximum power available for experiments in the H/M (approximately 11.7 kW as developed for the baseline configuration). The main considerations for proposing a new distributor are deletion of the requirement for a shunt regulator, provision for switchable bus and circuit protection, more commonality with the distributor in the A/A and increased power handling capability for growth.

The subsystem inverter and experiment inverter are isolated from each other in the Subsystem Power Distribution Box (SPDB). If either inverter fails, the load it normally supplies can be switched to the remaining unit.

The emergency power distributor is supplied from two auxiliary buses which are tapped from the main power buses in the A/A 30 VDC distributor. In Spacelab/Orbiter applications, the allocation for emergency power has been limited to 400 watts. For platform applications this can be increased as required up to the power handling capability of the emergency distributor itself and to higher levels with a new design.

Main power for experiments is available at outlets on the EPSPs, in floor cutouts and in the center aisle. Direct connections to the Experiment Power

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Distribution Boxes also can be made, subject to operational procedures. In addition, outlets are available at the 30 VDC distributor for experiments which exhibit unusually high power demands.

Power distribution in the Airlock/Adapter, as previously indicated in Figure 4.5.4.1-3, is similar to the H/M with regard to subsystem usage. There are no provisions for experiments in the A/A, however, power is available for distribution to a payload pallet. Subsystem AC loads in the A/A can be served from either of the two inverters shown in the figure

The EPS is monitored by the CDMS computer via RAUs to detect malfunctions and to perform power and energy management. A monitoring and control panel will be located in the A/A for direct crew interface with the EPS.

A summary of EPS equipment is given in Table 4.5.4.1-2. Power consumption listed for each unit is based on test data as given in Spacelab Electrical Power Status Report, Document No. RP-ER-0007, Issue No. 23. Note that no distributor is allocated for the Logistics Module; subsystem loads are fed via direct connector interfaces with the A/A. Subsystem inverters and experiment inverters as indicated earlier are identical but only subsystem inverters are included in the table.

Problem areas, remaining issues and major program impacts can be highlighted as follows:

- With a 12.5 kW Space Platform interface, power available for payloads is limited to the 2-3 kW range.
- Subsystem power consumption based on using Spacelab equipment accounts for nearly one-half of the power from the 25 kW Power System and over 90% in the case of the 12.5 kW Power System. This suggests examining selected items of subsystem equipment for possible power savings by (1) changes in mode operation, (2) design modifications or (3) replacement with more efficient equipment.
- Requirements for worst case contingency operation (no docked Orbiter) need to be defined since these in turn define the requirements for emergency power.
- To further assess the impact of on orbit maintenance, a determination is needed of the percentage of existing LRUs replaceable on the

Table 4.5.4.1-2

EPDS EQUIPMENT SUMMARY

UNIT	WEIGHT LB	VOLUME FT^3	POWER CONSUMPTION WATTS	UTILIZATION			
				LOG MOD	AIRLOC/ ADAPTER	HAB MOD	P/L MOD[1]
30 VDC POWER DISTRIBUTOR	53.0	1.20	15		1	1	
POWER CONTROL BOX	60.0	1.25	12				1
SUBSYST POWER DISTRIBUTION BOX	24.5	0.58	11		1	1	1
EMERGENCY POWER DISTRIBUTOR	5.8	0.08	1		1	1	1
EXP POWER DISTRIBUTION BOX	26.5	0.92	2			2	1
EXP POWER SWITCHING PANEL	9.9	0.44	1			7	4
INVERTER	73.2	1.29	200-325[2]		2	1	1
MONITORING AND CONTROL PANEL	8.9	0.43	35		1		1
LIGHTS	3.2	0.13	24[3]	2	13	13	7

(1) ONE-SEGMENT MODULE

(2) INDICATED RANGE FOR ALLOCATED AC LOADS BASED ON SPACELAB INVERTER PERFORMANCE DATA

(3) ASSUME A LOAD FACTOR OF 0.67 FOR AVERAGE POWER

ground which could be replaceable in flight using existing software.

- Growth Options
  - Extension of 30 VDC distribution buses. This approach may be constrained by power loss/voltage drop limitations depending on the amount of load and length added to the buses.
  - Distribution of regulated 120 VDC from the Power System interface to 30 VDC regulators on the platform. This approach reduces distribution losses and eliminates voltage drop problems but incurs losses in the Power System 120 VDC regulators which are in addition to losses in the platform 30 VDC regulators.
  - Consideration of the possibility of distributing unregulated high voltage power from the interface to 30 VDC regulators on the platform. This would avoid losses otherwise incurred in the 120 VDC regulators. However, a direct interface with unregulated high voltage power is not presently an option in the reference Power System (NASA Document PM-001).

4.5.4.2 Existing Hardware

Most Spacelab EPDS is usable without modification for platform applications. However, requirements for additional interfaces and increased power handling capabilities will exceed the design capability of the Power Control Box for use in the Airlock/Adapter and Habitability Module. New 30 VDC power distributors are needed in these areas. Similarly a new higher capacity emergency power distributor is needed for use in the A/A. Modifications of the existing Emergency Box also are probably for application in the H/M. A summary of the applicability of Spacelab EPDS hardware for use in the platform EPS is given in Table 4.5.4.2-1. Only major items are shown in the table.

As pointed out previously, improved access to some equipment will be required for on-orbit maintenance. The experiment inverter, for example, cannot be replaced in flight under nominal Spacelab conditions. Installation design of the new 30 VDC distributors and emergency distribution box will facilitate on-orbit removal and replacement.

For a special purpose Payload Module requiring more power than the Power Control Box can supply, the approach creates a new fuse box but allows use of

Table 4.5.4.2-1
APPLICABILITY OF SPACELAB HARDWARE TO PLATFORM EPS[(1)]

Item	Airlock/ Adapter	Habitability Module	Payload Module	Payload Pallet
Power Control Box	New box required • Higher power throughput needed • Additional power interfaces required	New box required • Built-in growth	Applicable	Not required
Emergency Box	New box required • Distributes emergency power to H/M, P/L modules, P/L pallet	Modification probable	Applicable • Input power supplied from Emer. Distributor in A/A	Not required • Emer. power supplied direct from Emer. Distributor in A/A
Subsystem Power Distribution Box (SPDB)	Applicable	Applicable	Applicable	Not required • S/S dc and ac power supplied from A/A SPDB
Experiment Power Distribution Box (EPDB)	Not required	Applicable	Applicable	Applicable • Power supplied from A/A 30 VDC Distributor and SPDB
Experiment Power Switching Panel	Not required	Applicable	Applicable	Not required
Inverters	Applicable	Applicable	Applicable	Not required

(1) Items noted as applicable are suitable for platform use, although in some cases all inputs, outputs, and internal functions may not be required.

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the Power Control Box as is. Total experiment power which can be supplied by this configuration is in excess of 12 kW.

The shunt regulator in the Power Control Box is not required in the baseline platform EPS because the bus overvoltage protection it affords is provided by the Power System. The new 30 VDC distributors which replace the PCB, therefore, will not include a shunt regulator. However, for possible alternative distribution schemes which would utilize 30 VDC regulators in the A/A and H/M as discussed in Paragraph 4.5.4.3, the shunt regulator function would be required. In this case, separate shunt regulators or other means of providing bus overvoltage protection would be provided.

4.5.4.3 Supporting Trades and Analysis

This section addresses approaches to supplying AC power, distribution alternatives for accommodating platform growth and considerations for emergency power.

Figure 4.5.4.3-1 shows several possibilities for supplying AC power in the Airlock/Adapter and Habitability Module. In each scheme, the subsystems and experiments are normally supplied from separate inverters as is the case in Spacelab. In Scheme A, a Spacelab inverter supplies experiments in the H/M. A new inverter supplies the subsystems in the A/A and H/M. If inverter No. 2 is lost, the experiments must be curtailed since no power is available from Inverter No. 1 (neglecting reserve capacity for handling subsystem peaks). Similarly, if Inverter No. 1 is lost, the experiments must be switched off and subsystem loads transferred to Inverter No. 2 but curtailed so as not to exceed the nominal 2.7 kW rating of the inverter.

In Scheme B, three Spacelab inverters are used, with two in parallel to supply the subsystem loads. If Inverter No. 3 fails, up to 1.7 kW of experiment load can be transferred to the subsystem bus, limited by allowances for subsystem and experiment peaks. This scheme offers some improvement over Scheme A for contingency modes but introduces the added complexity of operating inverters in parallel.

The third approach, Scheme C, builds on the arrangement in A but avoids paralleling inverters. Less power is available for experiments if

Figure 4.5.4.3-1

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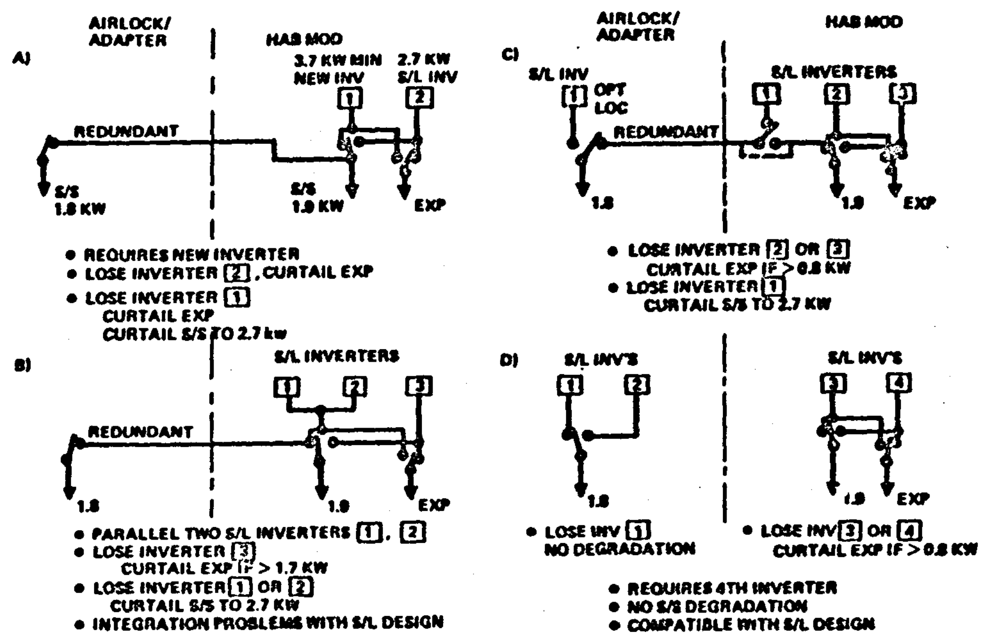
APPROACHES TO SUPPLYING AC POWER



Inverter No. 1 or No. 2 fails. By moving Inverter No. 3 to the optional location indicated on the figure, the redundant bus and bus switch in the H/M can be eliminated. This also results in improved voltage regulation at the loads.

Scheme D builds on the location option in C by adding a second inverter in the A/A and eliminating the bus extension from the H/M. This allows full operation of the subsystems when any inverter is lost but requires curtailing experiment power under specified conditions. An additional scheme, not shown, would modify the bus connections between the A/A and H/M to permit utilizing the fourth inverter as a common off-line backup for all three on-line inverters. This would avoid the need for curtailing experiment power but would require changing the Spacelab Subsystem Power Distribution Box (SPDB) to modify the AC power transfer bus and to bring it out of the box for routing to the A/A. Scheme D is baselined on the assumption that it allows use of the SPDB without modification. If Inverter No. 4 fails, experiment power will be limited until the failed inverter is replaced.

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AC power for payload modules is supplied from local inverters. This simplifies interfaces and gives maximum flexibility to payload design, i.e., use of AC power is not constrained by platform core-module converter loading allocations. However, where AC power requirements are relatively low, as indicated for the payload pallet subsystems in Table 4.5.4.1-3, provision is made to supply power from the designated Airlock/Adapter inverter.

Power distribution options for accommodating platform growth as shown earlier in Figure 4.5.4.1-3, provided for extensions of the main 30 VDC power buses and utilization of the Power System 120 VDC interface. An example of growth at 30 VDC is illustrated in Figure 4.5.4.3-2. Subsystem loads are shown for each module. A 5 kW experiment is assumed to be served from the distributor in the top module on the right. Resistance (R) values are based on data in the Spacelab Payload Accommodation Handbook, adjusted for higher capacity buses as needed. Circuit breakers (CB) have been added for isolating a faulted bus section in any of the core modules. Fuses (F) are shown for bus protection in the payload modules.

Figure 4.5.4.3-2

DC POWER DISTRIBUTION — GROWTH VERSION

(30V-DISTRIBUTION)

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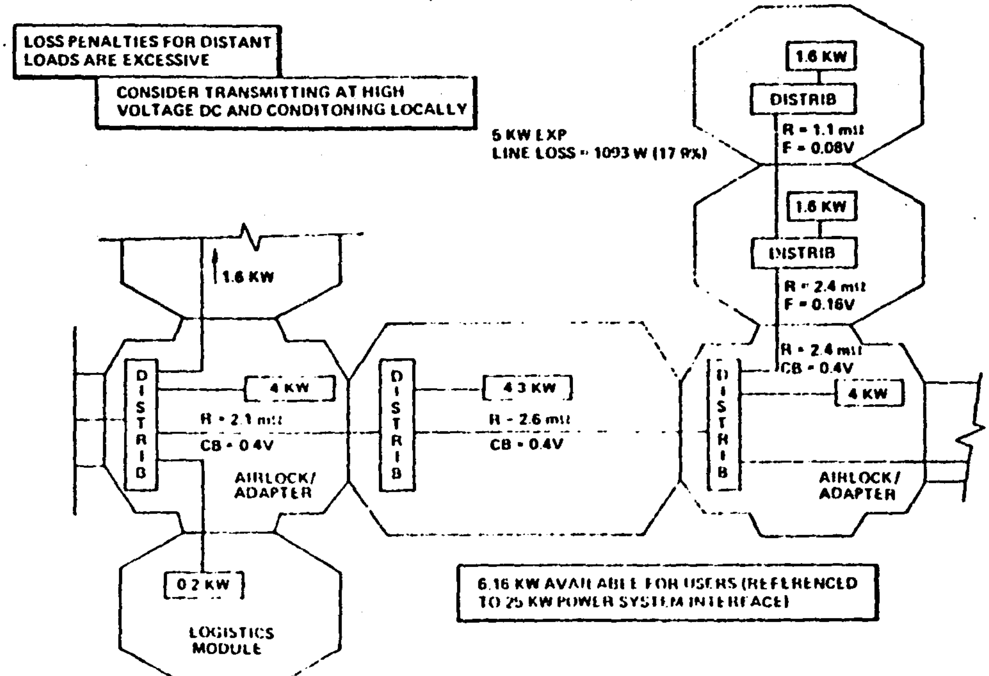

As a first approximation, when distribution losses are added to the subsystem loads, slightly over 6 kW is available for users. This assumes a 25 kW Power System interface. Distribution losses chargeable to the 5 kW experiment as noted on the figure are 1093 watts or nearly 18% of the total power available for this experiment. Voltage drops through the system result in low voltage at the experiment bus. Reduction of voltage drop by increasing bus sizes is one approach to improving this condition. Adding boost or buck-boost regulators at the loads is another. However, this introduces losses which are in addition to losses in the 30 VDC bulk power regulators in the Power System.

A third approach utilizes the Space Platform 120 VDC interface to bring power to distant loads at high voltage, thereby reducing losses. The high voltage power would be conditioned by regulators near the load as indicated in Figure 4.5.4.3-3. Losses in these regulators in turn would be in addition to losses in the Space Platform 120 VDC regulators. This suggests the possibility of bypassing (or eliminating) the 120 VDC regulators and interfacing directly with unregulated high voltage power from the Space Platform, as noted at the bottom of the figure.

Figure 4.5.4.3-3

TRANSMISSION VOLTAGE CONSIDERATIONS FOR DISTANT LOADS

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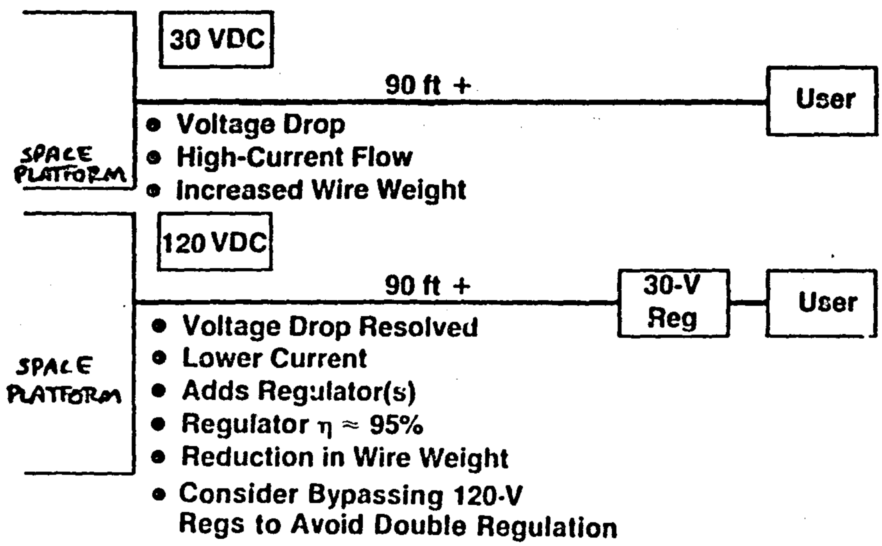

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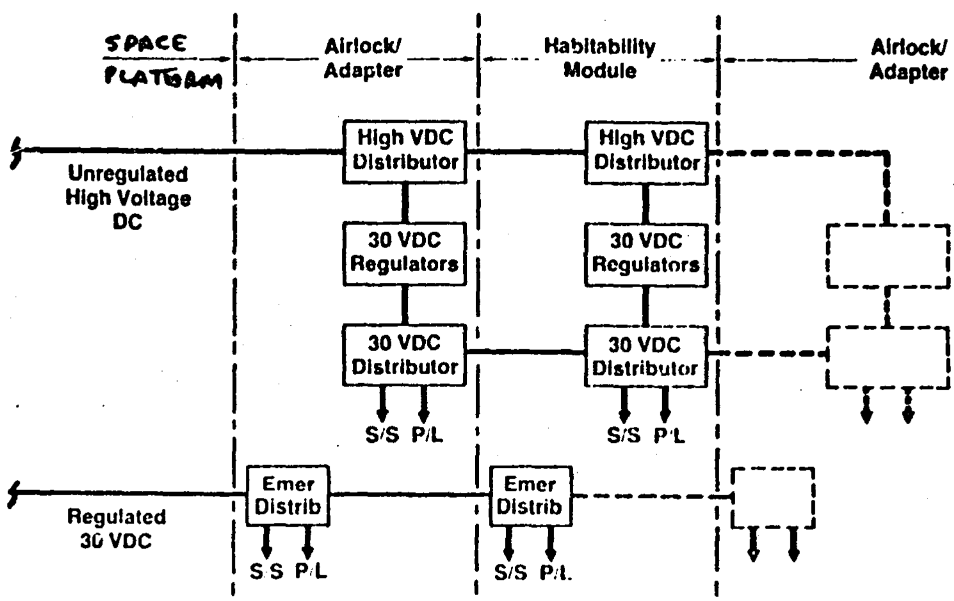
By extending this approach to include all primary power and not just that for distant loads, a system along the lines shown in Figure 4.5.4.3-4 could be considered. While not shown, this would also permit supplying high voltage power directly to special payloads if required. At present, however, an unregulated high voltage interface is not provided by the Space Platform (reference NASA Document PM-001).

To obtain maximum economy from such an interface, the 30 VDC regulators in the Space Platform would be removed and installed on the platform to the extent necessary to supply platform loads. The 30 VDC distribution system would be the same as described in Paragraph 4.5.4.1 with the exception of the emergency bus supply which would come directly from the Space Platform 30 VDC buses. This would more closely parallel the Spacelab distribution system where the emergency box is powered from auxiliary buses separate from the bus supplying Spacelab primary power.

Figure 4.5.4.3-4

CONCEPTUAL UNREGULATED HIGH VOLTAGE TRANSMISSION/ CONDITIONING INTERFACES

VFO406



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In the baseline platform distribution systen, consideration has been given to providing emergency batteries to back up the emergency power bus. The emergency bus is derived from the primary bus in the A/A 30 VDC distributor. Any failures in the supply ahead of the emergency distributors would result in either partial of total loss of emergency power, dpending on where the failure occurs. If the failure resulted in loss of primary power to loads normally backed up by the emergency bus, i.e., critical loads, then a critical situation would develop. A worst-case occurrence would be loss of all power from the Power System.

The baseline emergency bus system provides backup power to critical loads in the event the primary supply to these loads fails. As a minimum, this is intended to assure continuous operation of critical monitor and control functions for a non-catastrophic failure. The battery option shown previously would as a minimum extend emergency capability to include the more severe case of a temporary loss of both primary and (baseline) emergency power to a critical load or loads. The batteries would supply relatively low power until either primary or baseline emergency power is restored. A system such as that shown in Figure 4.5.4.3-4 would be less prone to these failures since the emergency supply is isolated from the primary supply all the way back to the Space Platform high voltage buses.

To provide emergency power for an extreme event such as complete and permanent loss of all interface power would require additional batteries. The crew would now be faced with a rescue operation. Some part if not all of the additional batteries should be output isolated from those shown in the baseline option and become part of a survival/rescue kit.

4.5.5 Structural/Mechanical

The conceptual design in this technical area was directed toward the MSP primary and secondary structural configuration for three major elements; (1) Habitability Module, (2) Adapter/Airlock Module and (3) Logistics Module. Available hardware was selected for each possible major element. However, detail design analysis must be conducted to verify the structural integrity of the available elements and to identify any modifications required peculiar to the MSP.

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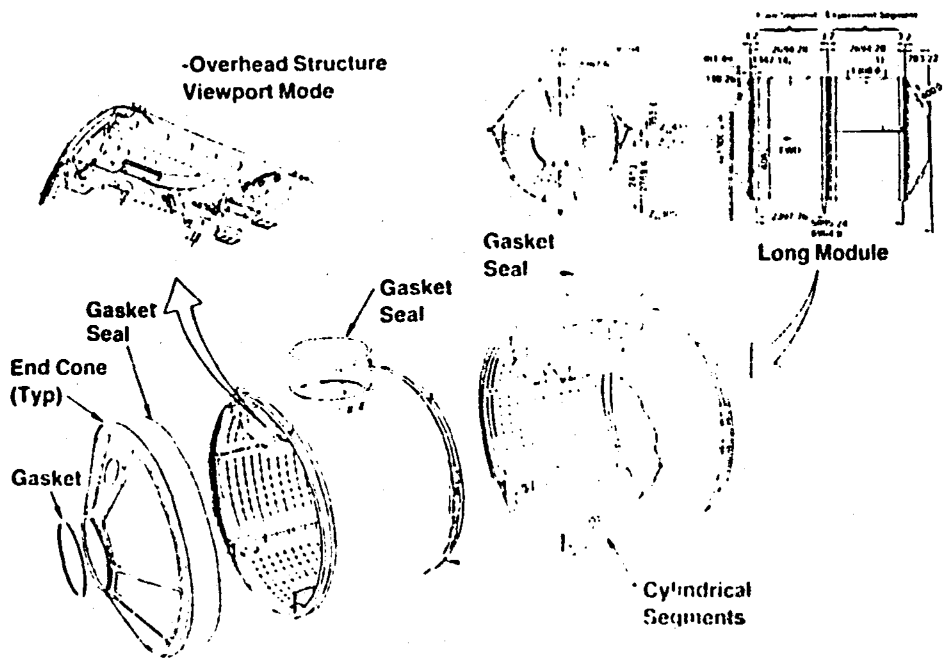
Habitability Module - Primary Structure

The MSP Habitability Module consists of two Spacelab cylindrical segments each 13.32 feet (4.06M) outside diameter x 8.79 feet (2.5 8M) long as shown in Figure 4.5.5-1. The cylinder is stiffened with equally spaced integral longitudinal ribs and rings spaced every 7.28 inches (185 mm) along the length. Integral end flanges provide a bolted and sealed interface with cylindrical segments and with the conical end domes. All stiffening ribs are located on the inside providing for equipment attach points. The membrane is 0.062 inch (16 cm) and the internal stiffeners are 0.98 inch (2.50 cm) high. Integrally stiffened conical structures are used to make the transition from 4.06M (159.8 in) to the 1.68M (5.51 foot) berthing interface. Each segment is equipped with a flange ring of 1.3M (51.18 in) internal diameter on the top to provide accommodation for an optical window/viewport assembly. When not used, the opening is closed with a coverplate.

The structural integrity of the Spacelab pressure shell must be verified to assure its ability to resist penetration by micro-meteoroids, to determine its

Figure 4.5.5-1
HABITABILITY MODULE — PRIMARY STRUCTURE



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damage resistance to pressure shell cracks and for assessing the module material resistance to time-dependent thermal cycling fatigue.

Habitability Module Secondary Structure

The internal main floor, shown in Figure 4.5.5-2, consists of a load-carrying beam structure designed to carry the equipment racks. The floor is covered by panels on the walking surface providing also for noise attenuation from the subfloor area. The floor also contains openings equipped with debris traps to allow cabin air return flow. Except for the center panel, all panels are hinged to allow underfloor access.

Modifications to the Spacelab floor will be required in the crew section (Experiment Segment) to accommodate structural support for the crew quarters. New hinged floor panels will be required to provide access to the trash management equipment mounted on the subfloor.

Figure 4.5.5-2
MAIN FLOOR SEGMENT

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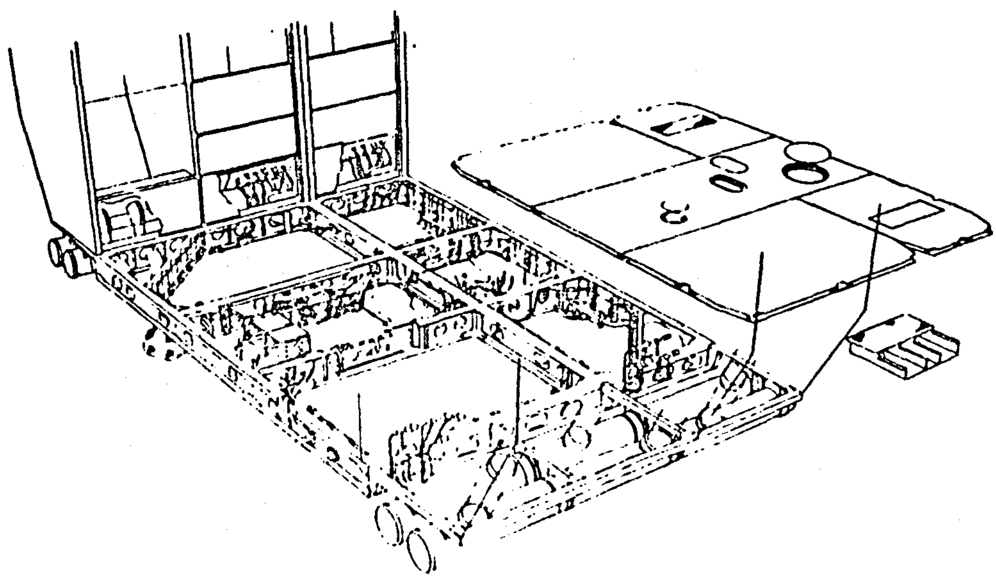

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The racks installed in the operations section (Core Segment) are standard 19-inch Spacelab racks designed to accommodate standard/non-standard laboratory equipment. The total number of racks is two double and two single in the Operations Section. Figure 4.5.5-3 indicates the locations and the numbering system of the racks. Racks 1 and 2 are reserved for subsystem equipment as shown in Figure 4.5.5-4. Three dimensional views of a single and double rack is given in Figure 4.5.5-5. Double Rack 4 is different from other double racks due to the accommodation of the experiment heat exchanger and cold plate. The galley structural design is similar to the Spacelab rack design except it is configured to occupy the remaining volume shown in Figure 4.5.5-3. Interface attachments to module floor will be standard.

The overhead structure supports the experiment racks and overhead storage containers as shown in Figure 4.5.5-6. All of the closeouts, light supports, etc., are provided by Spacelab. The Crew Compartment structure favored for

Figure 4.5.5-3

RACK NUMBERING SYSTEM

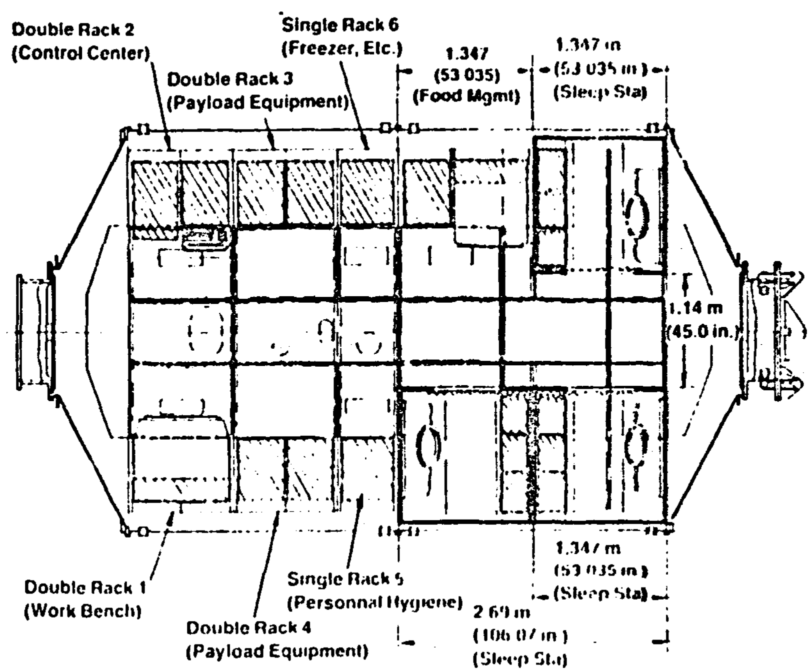

Figure 4.5.5-4

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RACK NO. 1 AND 2

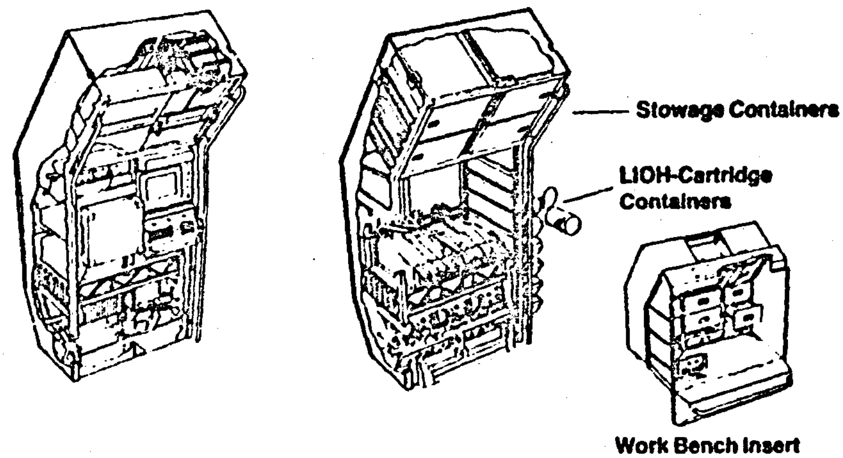

Figure 4.5.5-5

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EQUIPMENT RACKS

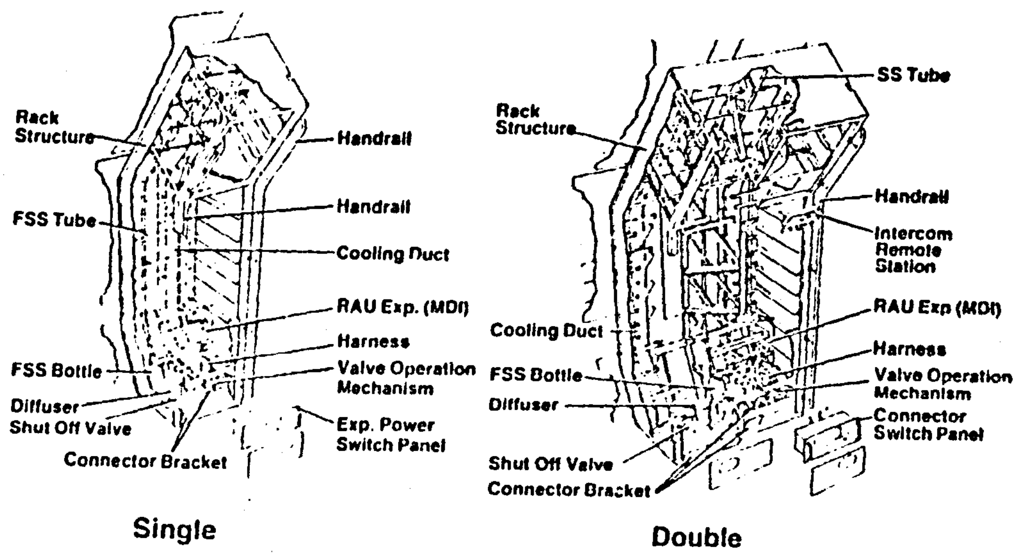
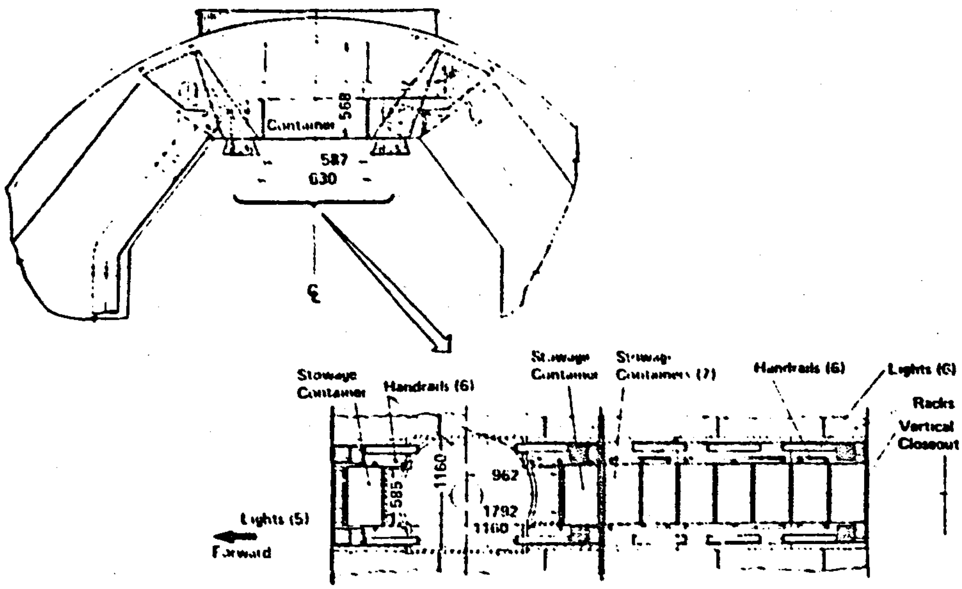


Figure 4.5.5-6

OVERHEAD STRUCTURE



High-Quality Window Viewport and 2 Containers **7 Containers**

for this study is a foam-filled isogrid partition designed to provide smooth surfaces for easy cleaning and provide a sound and light barrier.

Airlock/Adapter Primary Structure

The adapter primary structure, shown in Figure 4.5.5-7, must transfer the launch inertia loads to the Orbiter cargo bay attach points in accordance with the criteria defined in Orbiter ICD No. 2-19001 and must also contain atmosphere with negligible losses from leakage.

The flight loads are carried through four longeron fittings at Orbiter Sta. Xo 711.07 and Xo 939.20 and one keel fitting at Orbiter Sta. Xo 825.13 into an integrally stiffened pressure shell. The favored design is a 2219-T87 aluminum shell with all stiffening ribs internal to provide equipment attach points. The membrane is sized for a nominal operating pressure of 10.15 $\frac{N}{Cm^2}$ (14.7 psi); 10.34 $\frac{N}{Cm^2}$ (15.0 psi) is selected as the upper limit of the relief valve setting so that normal fluctuations in the pressure control system do not exercise the valve. The inside diameter of the cabin shell is

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Figure 4.5.5-7
ADAPTER/AIRLOCK PRIMARY STRUCTURE

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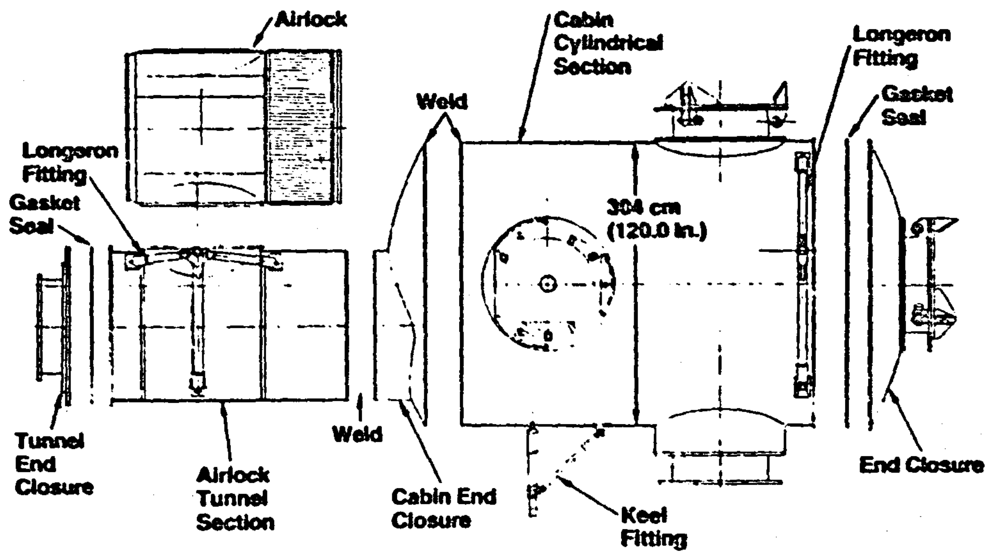

304 Cm (120.0 in). Using the minimum guaranteed tensile ultimate for 2219.T87 alum 42,700 $\frac{N}{Cm^2}$ (62,000 psi), and a factor of safety of 2.0, the minimum wall thickness for the cabin cylinder is

$$t = \frac{S.F.(PR)}{f_{tu}} = \frac{2.0\ (10.34)\ (152)}{} = 0.074 \text{ Cm } (.029 \text{ in})$$

An integral end flange provides a bolted and sealed interface with the end dome.

The Airlock tunnel portion of the Adapter is a 160 Cm (63.0 in) dia x 304 Cm (121.0 in) long section configured to interface with the Power System and the Airlock. An integral end flange provides a bolted and sealed interface with the passive berthing mechanism end closure. Also, a sealed/bolted integral interface is provided between the tunnel and the Airlock. The tunnel section is welded to the cabin end dome which is also welded to the Cabin Cylinder.

The .074 Cm wall thickness is adequate for pressure only, however, the damage resistance of the pressure shell must be sufficient to preclude explosive decompression from any reasonably conceivable accident. The desired damage

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resistance can be achieved by use of a sufficiently thick membrane or by the addition of integral ribs to increase the total bending stiffness and impact tolerance.

Critical crack length is a measure of the damage resistance of the pressure shell membrane. An accident which produces a rupture or tear smaller than the critical crack length will result in a leak rather than explosive decompression. If minimizing the pressure shell cost has primary importance and the pressure shell weight is secondary, the wall thickness of the optimum cylinder will be the thickness required at the longitudinal welds. The weld thickness selected for Spacelab is 4 mm (0.157 in). The optimum configuration will result from future detail design analysis based on current meteoroid/critical crack length data.

Airlock/Adapter Secondary Structure

The cabin section floor beam structure is designed much like the Spacelab floor and covered with hinged panels for access to the subfloor area.

The racks are standard 19.0 inch wide racks, similar to the Spacelab design, configured to accommodate standard equipment. The racks are mounted to the floor and installed as an integral unit.

The rack design for the tunnel section is an octagonal shaped structure joined to the pressure shell at the integral end closure ring by hanger support fittings. The rack is contained radially by symetrically located shear fittings on the cylinder wall.

Airlock Structure

The Airlock's primary structure, shown in Figure 4.5.5-8, is composed of machined aluminum sections welded together to form a cylinder with hatch mounting flanges. The upper cylindrical section and bulkheads are made of nonvented aluminum honeycomb.

Two semicylindrical aluminum sections are welded to the Airlock primary structure to house the ECLSS and avionics support equipment. Each semi-cylindrical section has three feedthrough plates for plumbing and cable routings from the Adapter to support the Airlock subsystems.

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Figure 4.5.5-8
AIRLOCK PRIMARY STRUCTURE

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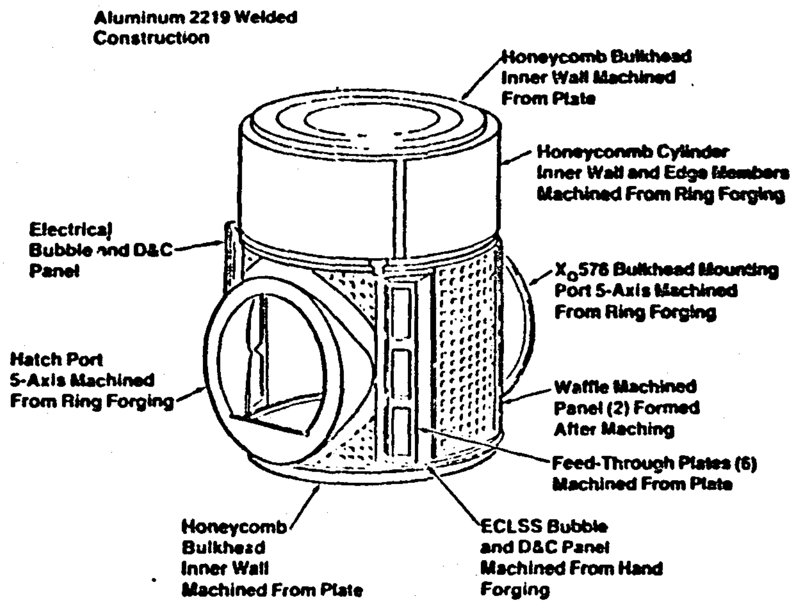

The Airlock is mounted to the tunnel via a series of bolts, using dual pressure seals around the hatch flange.

Logistics Module Primary Structure

The Logistics Module primary structure, shown in Figure 4.5.5-9, consists of a single Spacelab cylindrical segment 13.32 ft (4.06m) outside diameter x 8.79 feet (2.68m) long plus a 9.3 ft (2.84m) long x 14.16 ft (4.32m) dia unpressurized section. Integral end flanges provide a bolted and sealed interface with the cylinder and two conical end domes. The pressure cylinder stiffening ribs are located inside providing attach points for internal secondary structure. Integrally stiffened conical structures are used to make the transition from 4.06m dia to the 1.68m berthing and tunnel interface. A 1.14m (45.0 in) dia pressurizable tunnel extends from the aft end closure through the unpressurized section to the berthing system end closure. The tunnel is supported by an aft closure support structure.

The unpressurized section is an aluminum skin-stringer design attached to the aft conical pressure cylinder/end dome bolt joint.

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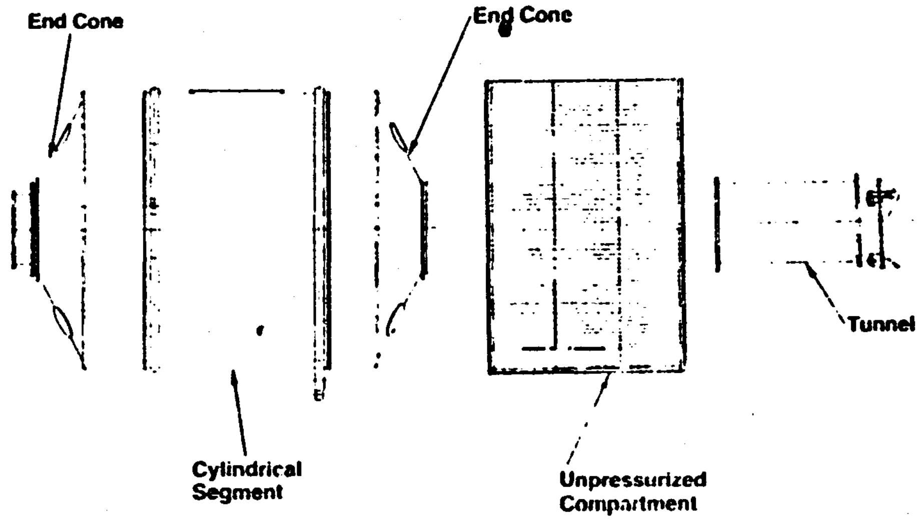
Figure 4.5.5-9

LOGISTICS MODULE PRIMARY STRUCTURE



Logistics Module Secondary Structure

The internal rack structure is an octagonal shaped structure jointed to the pressure shell at the integral end flange by hanger support fittings welded to the inside of the shell. The rack is contained radially by symetrically located shear fittings on the cylinder wall. The inner surface of the rack is configured to accommodate standard 19.0 inch wide equipment with flexibility to accommodate undefined non-standard equipment. The material and structural concept will be similar to the Spacelab design.

Hatches and Viewports

Two types of hatches are incorporated in the MSP, the Orbiter-type hatch and the Spacelab hatch. Elements of the MSP that incorporate segments of the Spacelab will use hatches developed for the conical end domes used on Spacelab. The other elements will use Orbiter-type hatches as shown in Figure 4.5.5-10. Each hatch contains a gearbox with latch mechanisms to allow the crew to open and/or close the hatch during transfers and IVA operation. The gearbox and latches are mounted on the low pressure side of each hatch with a gearbox handle installed on both sides to permit operation from either side of the hatch.

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Figure 4.5.5-10
ORBITER TYPE HATCH

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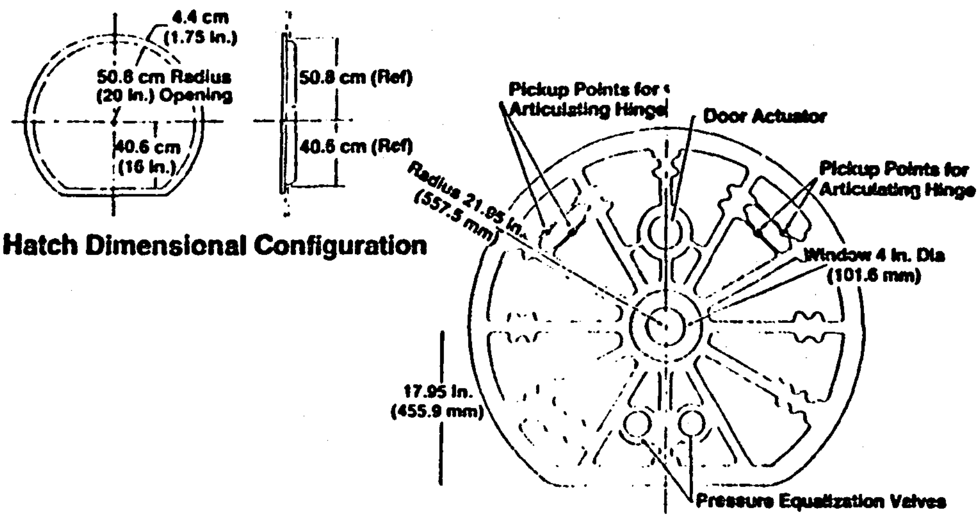

Hatch Dimensional Configuration

Hatch Cover Features

Each hatch has six latches, as shown on Figure 4.5.5-11; three are double-actuating to force the hatch away from the pressure seal surface during gearbox handle rotation and therefore, acts as a crew assist device. The latches are interconnected with "push-pull" rods and an idler bellcrank installed between the rods for pivoting of the rods. Self-aligning dual rotating bearings are used on the rods for attachment to the bellcranks and latches. The gearbox and hatch open support struts are also connected to the latching system, utilizing the same rod/bellcrank and bearing system. To latch or unlatch the hatch, a rotation of 440° (7.7 rad) on the gearbox handle is required.

A mechanical indicating system, displaying latches are locked and safe, is incorporated in the linkage mechanism on each side. Two pressure seals are incorporated on the hatch-side of the interface, one on the hatch cover and once on the structural interface. Pressure relief valves and differential pressure gauges are also incorporated on each hatch. Each hatch incorporates a 4.0-inch (101.6 mm) diameter window, as shown in Figure 4.5.5-12. Two types of hatch movements are considered for opening and storing the hatch cover.

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Figure 4.5.5-11
HATCH-LATCHING MECHANISM

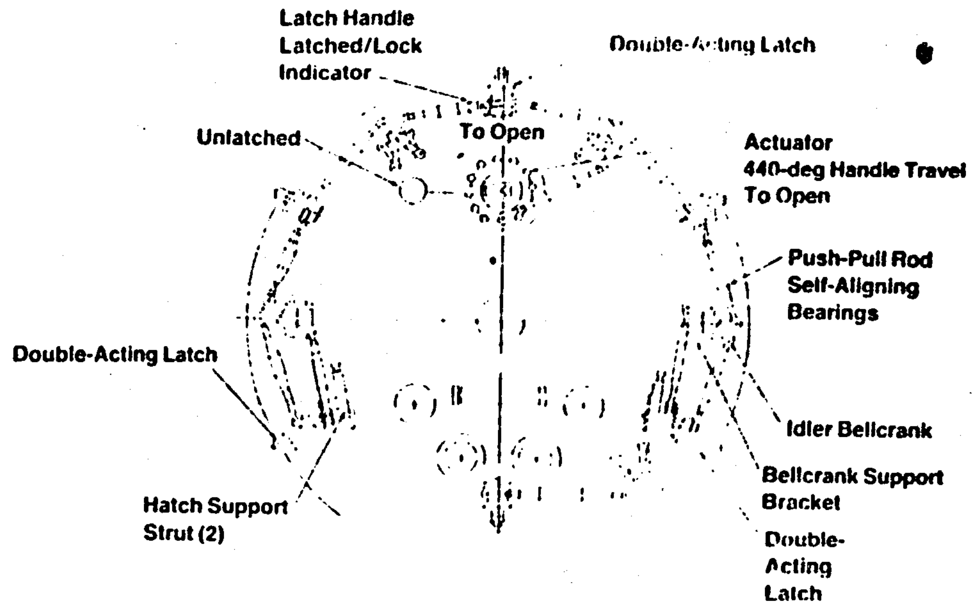
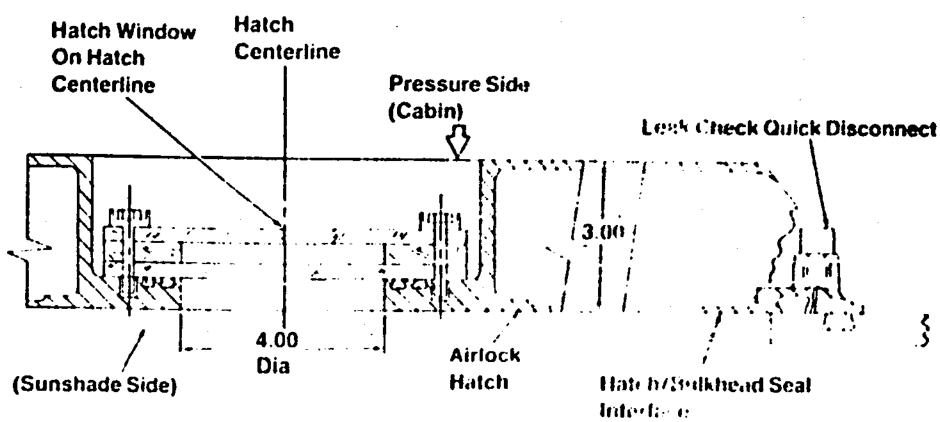


Figure 4.5.5-12
HATCH WINDOW CONFIGURATION



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Depending on the location and local clear area stowage envelope, a swing hinge or a translate mechanism will be used.

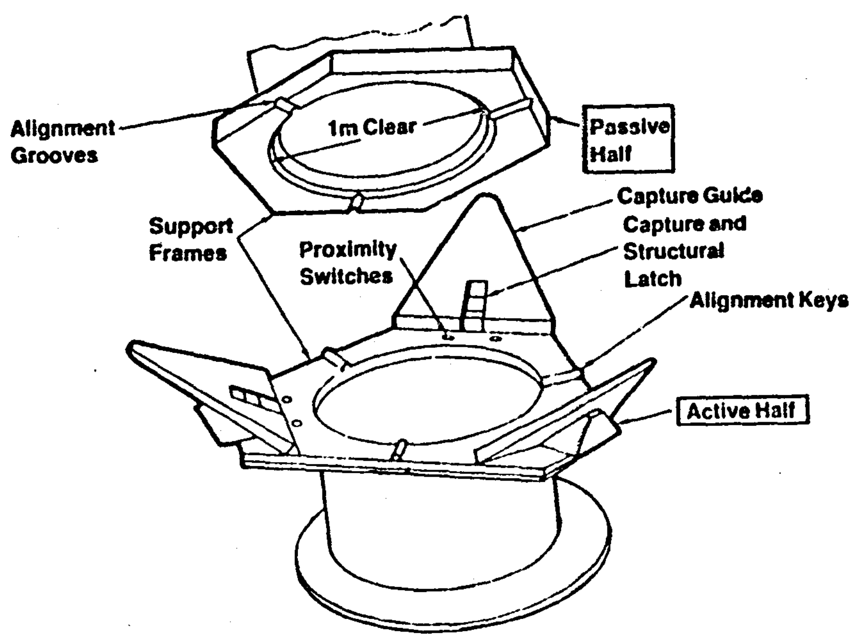
In addition to the viewport located in each hatch, two identical ports are provided in the Habitat Module. One is permanently installed in the aft cone while the other is incorporated in the 1.3 m diameter Adapter plate on top of the cylinder.

Berthing Mechanism

The berthing mechanism selected for this study, shown in Figure 4.5.5-13, is a modified version of the system developed by MDAC under Contract NAS9-16001 for the Johnson Space Center and documented in Report MDC G9346, dated February 1981. The concept would be modified to incorporated a pressure sealed interface between halves. During the development of the selected system, two major structural requirements were derived as part of the design criteria. They were:

Figure 4.5.5-13

BERTHING MECHANISM



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1. Structural Stiffness - The structural stiffness of the berthing system shall be a 4 x 10^6 ft-lb per radian in both bending and torsion. In the deployed position, the system shall exhibit no looseness of backlash in joints or drive actuators.
2. Structural Loads - The structural design bending and torsion loads applied at the berthing interface mechanism shall be 16,000 ft-lb.

Because of the fluidity of the platform's design and wide variations in mass and moments of inertia (MOI), the condition of two Orbiters berthed together, as shown in Figure 4.5.5-14, was used to establish load ranges. As illustrated, the interface moment produced by berthing the two Orbiters with an impact velocity of 0.1 ft-sec and a structural spring constant of 3.46 x 10^6 ft-lb/radian, would be 15,469 ft-lb. An interface moment of 16,000 ft-lb was used for the preliminary design of the system.

The platform studies assume that during the period when the Orbiter and platform are berthed, the stabilizations will be accomplished by the platforms

Figure 4.5.5-14

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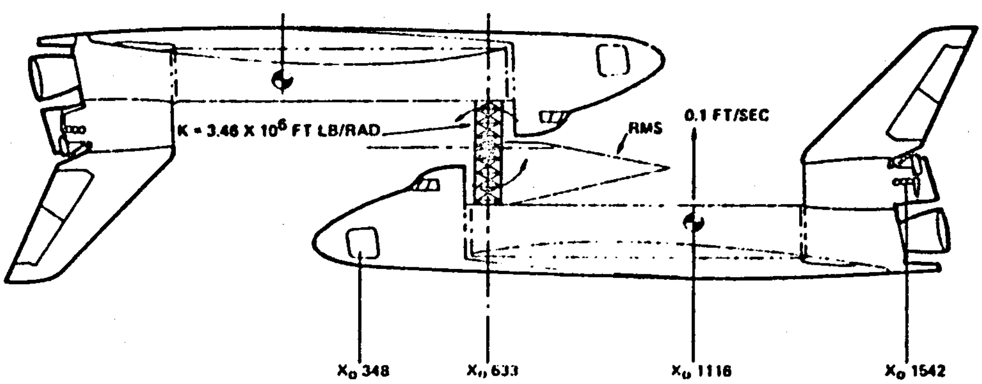
BERTHING SYSTEM LOADS



PITCH TORQUE RCS (ONE FWD AND AFT) [44,775 FT LB]
PITCH TORQUE VRCS (ONE FWD AND AFT) [1,243 FT LB]
PITCH TORQUE IMPACT CLOSING AT 0.1 FT/SEC [16,469 FT LB]

using CMGs. The control system frequency response dictates that structural natural frequencies should be above 0.1 Hz. Figure 4.5.5-15 shows that as the platform MOI increases the structural natural frequency becomes almost constant for a given spring rate. The structural stiffness for the berthing systems was established at 4 x 10 ft-lb/radian which maintains the structural natural frequency above 0.1 Hz for any platform regardless of MOI. The MOI of 17.62×10^6 slug ft^2 represents two Orbiters berthed together.

Based on the above analysis, the selected interface berthing mechanism is considered adequate, from a structural standpoint, to be used at all berthing interfaces regardles of the platform's configuration.

The passive half of the mechanism consists of a simple hexagonal frame with three alignment grooves in the face. The active side consists of a hexagonal frame with three alignment keys to match the grooves in the passive frame. Three triangular capture guides provide guidance for the passive frame to be

Figure 4.5.5-15

STRUCTURAL NATURAL FREQUENCY VERSUS PLATFORM MOI

CENTERLINE DOCKING STA Xo = 633

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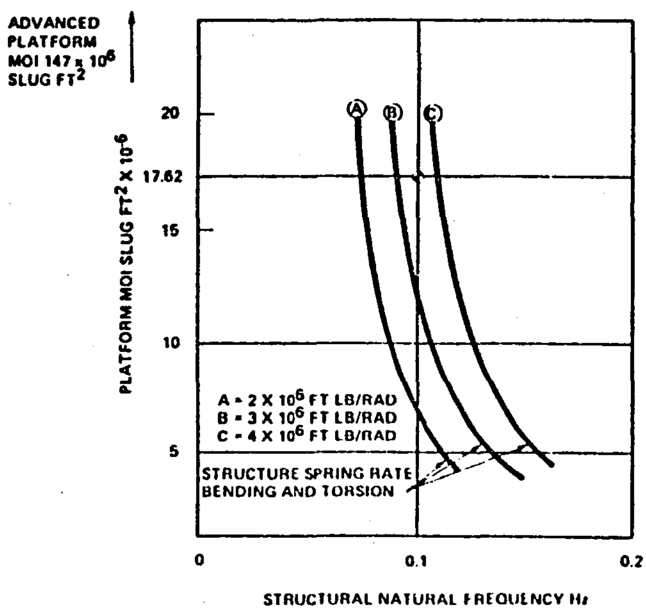

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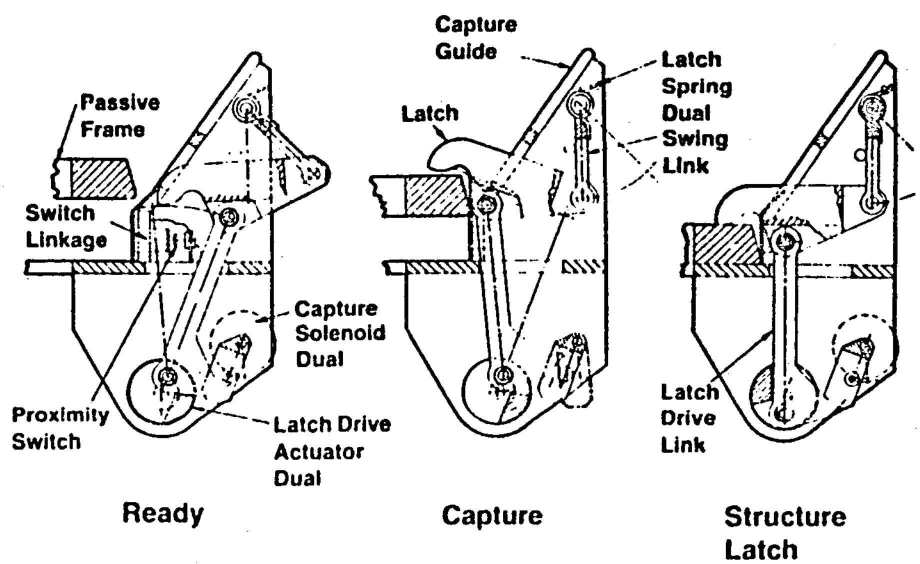
nested with the active frame. Contoured within the capture guide is the capture/structural latch mechanism.

Solenoids in each latch are activated by proximity switches in the fact of the active frame. The actuation of the solenoids release the capture/structural latches to contain and hold the passive frame. Dual motor actuators retract the latches to provide structural rigidity and alignment.

Figure 4.5.5-16 shows the mechanism in three states--ready, capture and structure latch. In the ready position, the spring-loaded latch is retracted below the surface of the capture guide. When the passive frame activated three or more of the six proximity switches, the frame is within the capture range of the latches. The capture solenoids are actuated and the latches, driven by springs, move to the capture position. The latch drive actuators pull the latch drive link down and clamp the two frames together and engage the alignment keys. The drive actuator springs and solenoids are dual to

Figure 4.5.5-16
CAPTURE AND LATCH MECHANISM

VF0962



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provide operation after one failure. The mechanism may also be driven manually by rotating the eccentric with a crank.

Alternate Berthing Considerations

Prior to selecting the favored berthing system, a cursory evaluation of other candidate systems, shown in Figure 4.5.5-17, was made. Effort was made to select a system that would satisfy berthing requirements at all interfaces. Key issues such as weight, mechanical complexity and physical envelope, were of prime importance. The six concepts were compared and given positive and negative grades for a set of 10 evaluations criteria. Configuration 6 was selected. The international docking assembly is one of the viable candidates, however, the clear passage through is approacimately 80 cm (30.5 in), plus the envelope restricts its use on all known interfaces. Modifications to the international system to make it acceptable for use on the MSP are possible and a detailed trade analysis is recommended before a final selection is made.

Figure 4.5.5-17

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EVALUATION CRITERIA FOR BERTHING LATCH INTERFACE MECHANISM

EVALUATION CRITERIA	CONFIGURATION 1 ASTP	2 RMS END EFFECTOR	3 V-JOURNAL TRUNNION	4 SQUARE FRAME	5 BALL CASTER AND SOCKET	6 HEXAGONAL FRAME (SELECTED)
1. DEVELOPMENT STATUS	+	+	-	-	-	-
2. CAPTURE MECHANISM IMPLEMENTATION	+	-	-	+	-	+
3. UMBILICAL ACCOMMODATION	-	+	+	+	+	+
4. ADAPTABILITY TO ANDROGYNOUS SYSTEM	+	+	+	+	-	+
5. CAPTURE MISMATCH CAPABILITY	+	-	+	+	+	+
6. WEIGHT	TBD	TBD	TBD	TBD	TBD	TBD
7. TOLERANCE AND THERMAL SENSITIVITY	-	-	+	+	+	+
8. LOAD TRANSFER CAPABILITY	+	-	+	+	+	+
9. MECHANICAL COMPLEXITY (COST)	+	-	+	+	+	+
10. SIZE (ENVELOPE)	-	-	+	-	+	+

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The system selected for this study provides a 1.0 m (40.0 in) diameter clear passage between interfaces and the physical envelope permits its use on all interfaces such as MSP/Orbiter. Pallet/MSP, Module to Module, Power System/MSP and Power System/Pallet.

Berthing Umbilical Interface

The favored berthing umbilical interface shown in Figure 4.5.5-18 consists of three mechanisms mounted behind the three clear sides of the hexagonal frame of the active half. The mating half of the umbilicals are fixed to the corresponding sides of the passive half. Two mechanisms are required to carry the electrical power, data and coolant fluid lines. The third mechanism position is available for potable water, waste water and atmosphere.

The engagement sequence of the active side of the umbilical is illustrated by Figure 4.5.5-19. The umbilical mechanism on the active half is stowed behind the face of the berthing frame and the mating connectors are fixed on the outside of the passive frame. The umbilical carrier is mounted on linkage

Figure 4.5.5-18

UMBILICAL INTERFACE

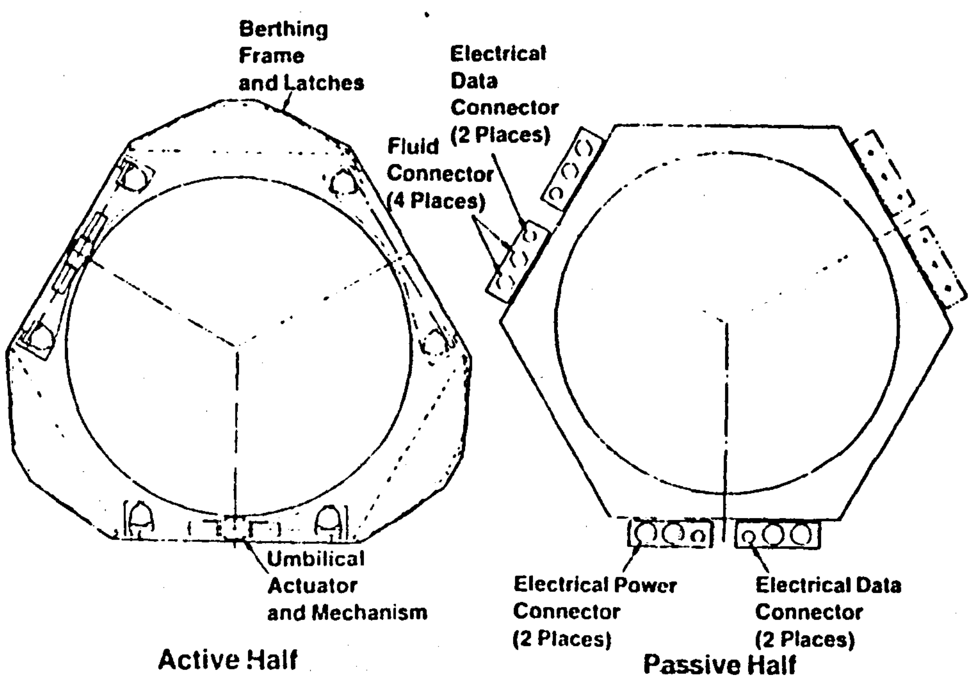

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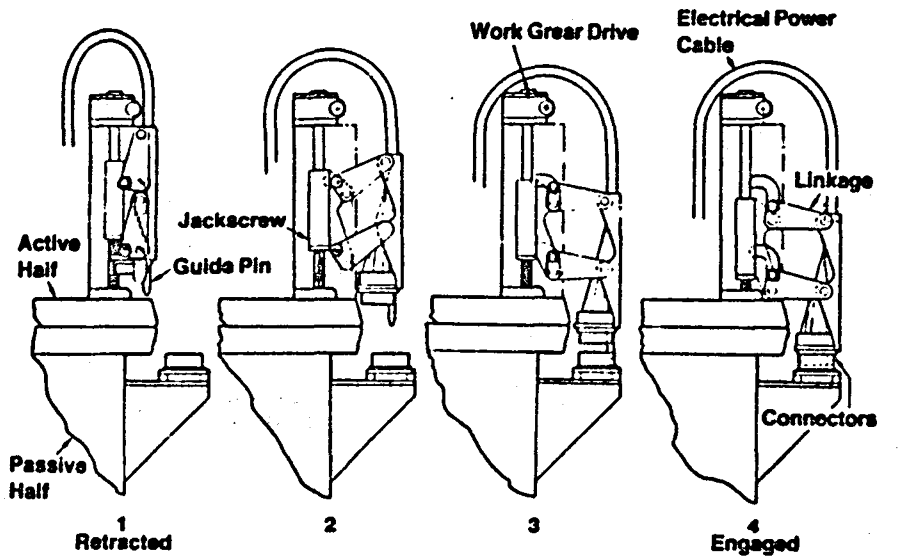
Figure 4.5.5-19

UMBILICAL INTERFACE ENGAGEMENT SEQUENCE



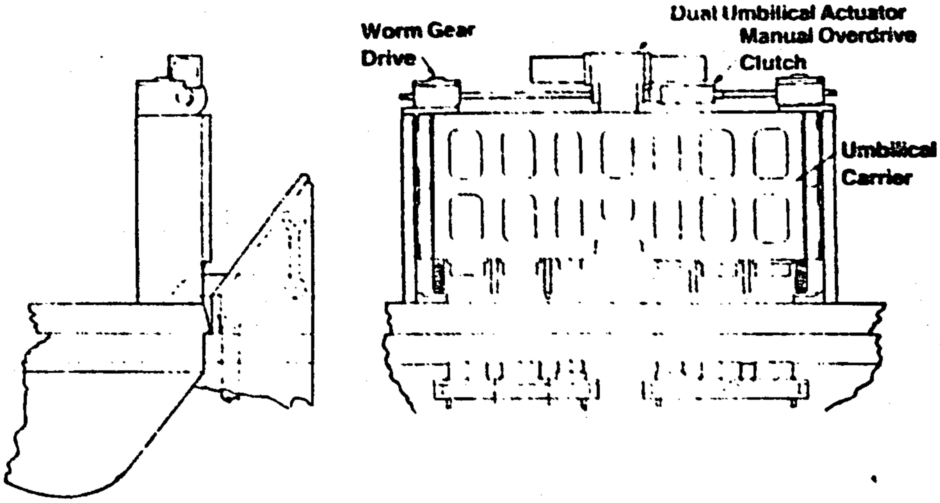
which is rotated by cam followers. As the links' pivot points are moved down by the jackscrew the umbilical carrier is moved outboard and down engaging the fixed side of the umbilical. Figure 4.5.5-20 shows the carrier retracted and two active halves mated which is also a requirement of the design. A clearance slot in the center of the carrier is provided to allow engagement of the structural latch.

Dual motors are used to drive the two worm gears and jackscrews. A clutch is provided in the drive shaft to allow operation by an EVA astronaut if both motors fail to operate.

Internal Vs External Umbilical

Installation - The favored external umbilical system was selected primarily for two reasons: (1) overall envelope of the berthing system and (2) clear unobstructed access between berthed modules. Also, the concept selected accomplishes structural berth before the umbilical engages, thus eliminating the misalignment tolerances and physical behavior of berthing from the umbilical system. In addition, cutouts are provided in the Spacelab conical dome for interface services that penetrate the pressure shell, thus services can be

Figure 4.5.5-20
UMBILICAL INTERFACE CARRIER



provided to the umbilical with no modification to the end dome. In addition, failure of a liquid or gas interface connector would not contaminate the pressure volume adjacent to the problem since space limitations will require at least one hatch to be open to repair an internal system. Maintenance of the external system is via EVA. Since EVA is a standard method to be employed for maintenance of major elements of the MSP, umbilical maintenance would not add to the overall support requirements of the MSP.

An internal design, shown in Figure 4.5.5-21, is a viable alternative and could be sized to accomplish the desired interface mating. Enlarging the diameter of the pressurized portion to permit a 1.0 m clear passage, may require a modified Spacelab and dome. Also, a larger envelope may negate use of the berthing mechanism on all berthing applications.

A detailed evaluation and impact study will be required before a final concept could be recommended.

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Figure 4.5.5-21

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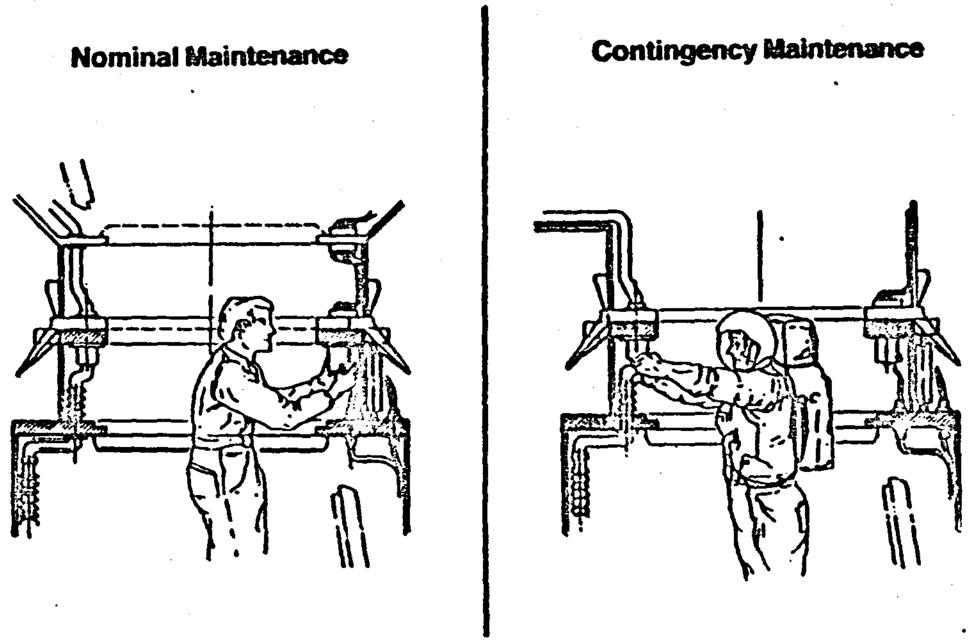
INTERNAL UMBILICAL CONCEPT



Structural Analysis

An overall assessment of the MSP structure was made to surface concerns that must be addressed in the future. Figure 4.5.5-22 lists the concerns for each of the MSP modules and the assembled platform. From a systems standpoint, docking joint compliances and thermal distortion effects on pointing are the most significant items.

Docking joint compliances require an in-depth analysis to ascertain dynamic response/MSP attitude control interaction. Attention must be paid to design details that affect joint compliance and an iterative design/analysis process may be required to solve the compliance problem.

Thermal distortion is a pointing problem because orbit position and structural temperatures are related and are transient parameters. Estimates of stable temperatures, temperature gradients and repetitive temperature changes are necessary to adequately predict structural deformation and the capability for fine pointing. Experiment location on the platform is also a factor in

Figure 4.5.5-22

STRUCTURAL/MECHANICAL CONCERNS

VFO736

Spacelab Module

- **End Dome Strength For Docking Loads**
- **10-Yr Life Limitations**

Airlock/Adapter Module

- **High Pressure System Design Assurance**
  - **Design Factors of Safety**
  - **Fracture Mechanics Analysis**
  - **Meteoroid Penetration Protection**
- **Airlock Fatigue Life**

Assembled Platform

- **Docking Joint Compliances Increase Assembly Flexibility (Dynamics/Control Problem)**
- **Thermal Distortions Affecting Pointing Requirements**
- **Design For "Leak-Before-Failure" Condition to Preclude Catastrophic Pressure Loss**
- **Reboost Loads on Modules and Connections**

pointing when more than one experiment is pointing at the same time. A design limit needs to be established for platform controlled pointing. A systems study of experiment pointing requirements is needed to define the limits. Any requirements exceeding the limit will necessitate auxiliary pointing equipment on the experiment.

Figure 4.5.5-23 shows the analysis tasks that need to be performed to assure good structural definition of the platform future tasks deal with long platform life and crew safety. Figure 4.5.5-24 describes fracture mechanics analyses used to evaluate long life and safety. Fracture analyses on the Spacelab Module could be performed in the near future since Spacelab structure is already well defined.

Preliminary platform factors of safety have been defined in Table 4.5.5-1. These factors were derived from similar factors of safety for the Orbital Workshop (OWS) program. A document similar to DAC Report 56612B, Loads and Structural Design Criteria, from the OWS program is recommended for the platform program as it evolves into full scale development.

Figure 4.5.5-23

REQUIRED STRUCTURAL/MECHANICAL TASKS

VF0737

(This Contract)	• Define Design Factors of Safety For All Platform Components
(Follow-On)	• Estimate Maximum Hole Diameter In Spacelab Module for "Leak-Before-Failure" Design
(Follow-On)	• Review Spacelab Module Design For Life Limitation Components
(Follow-On)	• Perform Preliminary Fracture Mechanics Analysis on Spacelab Module (See Example Statement of Work Provided to ERNO For FOD Study. Analysis Not Performed Since US Capability Is Required)

Figure 4.5.5-24

FOLLOW-ON FRACTURE MECHANICS ANALYSIS*
(ONLY PRELIMINARY TYPE REQUIRED)

VF0738

Objective Assure That No Major Mods Are Required for Spacelab Module

- Establish the Maximum Flaw Size That Can Exist After Proof Tests
- Determine the Design Fatigue Spectrum For the Pressure Shell, Limit Design Stresses, Temperature, and Cycles/Time For the Following Mission Regimes:
  - a) Ground
  - b) Prelaunch
  - c) Launch and Ascent
  - d) On-Orbit (As a Function of Duration and Repeat Flights)
- Determine the Maximum Flaw Growth After the Proof Tests Using Available Material (MDAC) Flaw Growth Rate Characteristics and the Design Fatigue Spectrum (Using a Factor of 4 on Design Cycles)
- Demonstrate Either of the Following With Analysis Results:
  - a) Maximum Flaw After Proof Test Does Not Grow Through the Thickness or Become Critical
  - b) The Flaw Does Grow Through the Thickness But Does Not Become Critical (E.G., Leak Before Fail Condition). If This Condition Occurs, Show That Spacelab Atmosphere Leakage Is Very Low and Can Be Detected Before Endangering the Crew

*Using MDAC-Modified MSFC Code (Used Recently on SRB)

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Table 4.5.5-1

PRELIMINARY FACTORS OF SAFETY AND STRENGTH REQUIREMENTS

1. GENERAL REQUIREMENTS

1.1 DESIGN YIELD LOAD

At design yield load, there shall be no yielding of the structure which may result in impairment of functional requirements of any OWS system.

1.2 DESIGN ULTIMATE LOAD

At design ultimate load, there shall be no failure or instability of any structural assembly.

2. FACTORS OF SAFETY

The following factors of safety shall be used for the design and analysis of all existing, modified and new structural elements.

2.1 GENERAL STRUCTURE

These factors of safety are applicable to all general structure except where specifically defined.

A. Manned Vehicle
   1. Yield factor of safety = 1.0
   2. Ultimate factor of safety = 1.40
B. Unmanned Vehicle
   1. Yield factor of safety = 1.10
   2. Ultimate factor of safety = 1.25

2.2 HABITATION AREA - PRESSURE ONLY

The factors of safety for the Habitation Area pressure are as follows:

A. Unmanned vehicle (prelaunch, launch, boost)
   1. Proof pressure = 1.05 times limit pressure
   2. Yield pressure = 1.10 times limit pressure
   3. Burst pressure = 1.25 times limit pressure

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Table 4.5.5-1 (continued)

B. Manned vehicle (on-orbit)
   1. Proof pressure = 1.50 times limit pressure
   2. Yield pressure = 1.10 times proof pressure
   3. Burst pressure = 2.00 times limit pressure

2.3 WINDOW, INTERNAL PRESSURE ONLY

The factors of safety for the internal pressure of the window are as follows:

A. Proof pressure = 2.00 times limit pressure
B. Burst pressure = 3.00 times limit pressure

NOTE: These factors apply to the window pane (i.e., glazing) only.

2.4 FLUID OR PNEUMATIC SYSTEMS

The factors of safety for the fluid and pneumatic systems are as follows:

A. Flexible hose, tubing, ducts, fittings, less than 1.5 in. diameter (existing).
   1. Proof pressure = 2.00 times limit pressure
   2. Yield pressure = 1.10 times proof pressure
   3. Burst pressure = 4.00 times limit pressure

   Flexible hose, tubing, ducts, fittings of 1.5 in. diameter or greater (existing)
   1. Proof pressure = 1.50 times limit pressure
   2. Yield pressure = 1.10 times proof pressure
   3. Burst pressure = 2.50 times limit pressure

   Flexible hose, tubing, ducts, fittings (new design)
   1. Proof pressure = 2.00 times limit pressure
   2. Yield pressure = 1.10 times proof pressure
   3. Burst pressure = 4.00 times limit pressure

B. Actuating cylinders, valves, filters and switches (existing) and/or new design)
   1. Proof pressure = 1.50 times limit pressure
   2. Yield pressure = 1.10 times proof pressure
   3. Burst pressure = 2.50 times limit pressure

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Table 4.5.5-1 (continued)

C. Reservoirs (existing)	
1. Proof pressure	= 1.50 times limit pressure
2. Yield pressure	= 1.10 times proof pressure
3. Burst pressure	= 2.50 times limit pressure
D. Reservoirs (new design)	
1. Proof pressure	= 2.00 times limit pressure
2. Yield pressure	= 1.10 times proof pressure
3. Burst pressure	= 4.00 times limit pressure

2.5 ASTRONAUT TETHERS AND ATTACHMENTS

The factors of safety for the astronaut tethers and attachments are as follows:

A. Yield factor of safety = 1.10

B. Ultimate factor of safety = 2.00

2.6 TEMPERATURE

A factor of safety of 1.0 shall be applied to temperatures as applied to effects imposed on the structure.

2.7 MALFUNCTION

A factor of safety of 1.0 shall be applied to loads resulting from a malfunction.

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4.5.6 Habitability Subsystem

The Habitability Subsystem supports the crew by providing for food and waste management, medical provisions, personal hygiene, sleep provisions, exercise and recreation facilities and IVA/EVA support. Concepts to provide these functions were selected to assure the psychological and physiological well being of the crew. This is accomplished without undue penalthy to the MSP or without diluting resources available to experiments. Full use was made of suitable existing hardware and technology. In the paragraphs below, the design will be described in detail along with supporting trade and analysis data and rationale.

4.5.6.1 Subsystem Definition

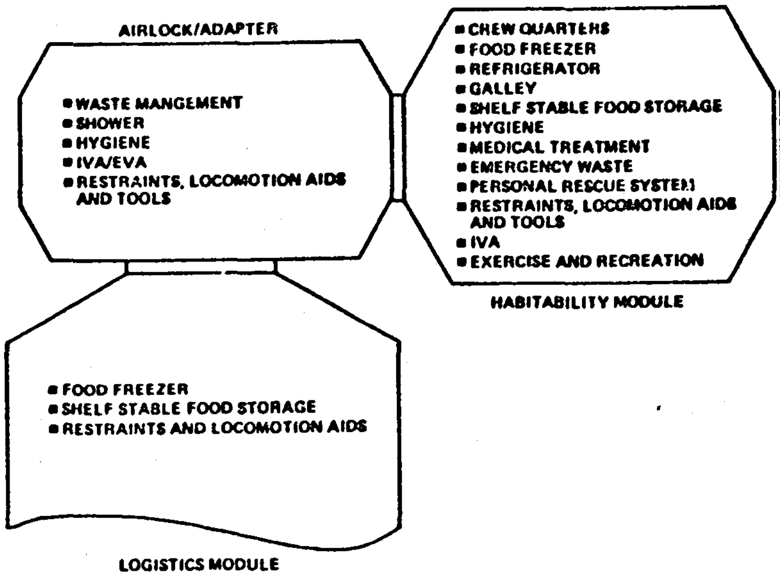
Essentially existing concepts are used in the design which have been proven on past programs or will be proven early in the Shuttle program. Food concept is a combination of Skylab and Shuttle concepts of shelf stable storage approach supplemented with frozen foods and limited fresh foods. An improved version of the Skylab full body shower is also planned Most of the remaining habitability provisions will be Shuttle program derivative.

4.5.6.1.1 Description - The concepts selected to accomplish the habitability functions and their arrangement in the basic MSP are shown in Figure 4.5.6.1.1-1. All essential equipment are duplicated or a second method of satisfying the function is provided and separated between the two pressurizable compartments. In this way habitability support will be provided to the crew in the event one of the pressurizable compartments becomes nonviable to the crew. Essential functions which are duplicated in this manner are waste mangement, food, water supply, IVA and rescue capability.

The waste management system uses the Shuttle commode assembly which consists of a waste collector with integral slinger, two fan/urine separators, odor and bacteria filters and associated valves and controls. The commode assembly collects urine, waste water, feces and vomitus. The urine and waste water is pumped to a waste storage tank. The feces and vomitus is stored and vacuum dried in the waste collector.

Figure 4.5.6.1.1-1

SELECTED CONCEPTS AND ARRANGEMENT
– HABITABILITY SUBSYSTEM –



Collector nominal capacity is 210 man/days after which time the assembly must be replaced. Every 180 days the three-man crew would require two to three units. Current design does not allow for easy replacement and the entire assembly comes as a unit whereas only the container unit requires replacement in the MSP application. Some redesign is recommended which would allow efficient replacement of the container only.

Another option considered would install the waste management assemblies in the Logistics Module. This would eliminate the need to replace the assemblies on orbit with the associated space vacuum connections.

A whole body shower is provided in the Airlock/Adapter. This is a modified Skylab unit which has been redesigned to reflect lessons learned from Skylab. Additional wash basin-type facilities are included in both basic compartments.

The food diet selected for MSP is composed primarily of shelf stable foods and frozen food. The diet will be supplemented with fresh foods at Shuttle revisits. A caloric value of 2800 calories/man-day was used for sizing the

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diet which should be adequate in most cases; extensive and strenuous EVA will require larger amounts of resupply food.

Most of the food will be stored in lockers and freezers inside the Logistics Module. At least seven days of food will always be kept in a smaller freezer and refrigerator in the Habitability Module. In the event of Airlock/Adapter loss, this food will sustain the crew until remedial action restores use of the Airlock/Adapter or until a Shuttle rescue vehicle arrives. Normal crew procedure will be to use the food from the Habitability Module area.

The Habitability Module will be the crew "off time" area which contains the crew quarters, exercise and recreation. An emergency medical kit is also located in this area. Also located near the crew quarters is the galley which contains a water heater, water dispenser, over and pull-out work surfaces and closure doors to provide meal assembly areas and "0" g serving tray mounts. Serving trays contain individual inserts that are kept at serving temperatures in the warming oven. The water system heater elevates room ambient temperature water to 160°F and dispenses chilled water at 50°F. Storage is also provided for food, trays, condiments, personal and galley cleanup wipes and trash management.

Provisions are included in the design for the crew to be rescued by a Shuttle in the event either pressurized volume is lost and cannot be repaired. If the Airlock/Adapter is lost, the crew can be rescued in the Personal Rescue System (PRS). This is identical to the planned rescue mode of a crew from a disabled Shuttle. The MSP crew would enter the PRS and then be transported by a Shuttle EVA team through the rear hatch to the Shuttle.

Rescue from the Airlock/Adapter would be with the EVA suits which are stored in the Airlock area.

4.5.6.2 Characteristics

Table 4.5.6.2-1 gives the characteristics of the major fixed equipment for the Habitability Subsystem. The total fixed weight amounts to 1356 lbs, requires a volume of 163 cubic feet and will use an average of 318 watts.

Table 4.5.6.2-1

HABITABILITY SUBSYSTEM CHARACTERISTICS - INITIAL CONFIGURATION

Equipment	No. Req'd	Weight (lb)	Volume (cu ft)	Power Ave/Peak (watts)	Location
Food Freezer	1	90	32	120/120	LM
Food Refrigerator/Freezer	1	40	8	80/80	HM
Galley	1	166	24	83/1000	
Shower	1	90	60	20/600	A/A
Hygiene	2	60	4	10/300	
Medical Kit	1	20	1	--	HM
Waste Management	1	93	12.2	5/135	A/A
Exercise and Recreation Kit	1	80	4	--	HM
IVA Masks	6	42	1.2	--	A/A, HM
Extravehicular Mobility Unit (EMU)	3	525	5.6	N/A	A/A
Trash Compactor	1	76	8	5/200	HM
Personal Rescue Spheres (PRS)	3	77	3	--	HM

The bulk of the expendables will be food, 1400 lbs for each 180-day resupply. Other expendables including waste management expendables, clothing, bedding, wipes, trash bags and miscellaneous items will weigh about 880 lbs. Therefore, the estimated total expendables will weigh 2280 lbs and occupy 136 cu ft of volume.

4.5.6.3 Remaining Issues

The Habitability Subsystem concepts chosen for the Basic MSP essentially represent Skylab/Orbiter designs and as such do not extend the state of the art significantly. Most of the remaining issues involve the extent that these essentially first generation crew support concepts are replaced with more advnaced concepts which reduce expendables and improve crew accommodation at the expense of higher initial cost and program risk.

Clothes Washing

Numerous items used by the crew which are expendable in the current concept could be washed and reused. These include such items as clothes, towels and bedding. Over a one-year period the resupply for these items amounts to about 1300 lbs. Expendables will be larger if extensive EVA is used because of the need to wash or replace the EVA under-garment after each use. This relatively large resupply amount makes the development of a clothes washer appear attractive and should be considered in subsequent studies.

Waste Management Expendables

The current Shuttle design of the commode assembly designed not to be replaced on orbit. Because of the Shuttle planned mission duration of seven days the commode, which is designed for 210 man-days, is ample for any crew size fore-seen. However, this sizing will require two to three commode changeouts every 180 days for the MSP. A more efficient design would use a removable liner which would be bagged for earth return thereby eliminating most of the large resupply requirement. Replacement at the tank level would also save significant resupply/return weight but this would not be as significant as the replaceable liner concept.

Because of the high penalties associated with using the Shuttle commode as currently configured, this assembly is identified as a prime candidate for redesign.

4.5.6.4 Existing Hardware

Many of the concepts selected for use in the Basic MSP is existing hardware from Shuttle. Table 4.5.6.4-1 demonstrates use of existing hardware and lists eight major subsystem elements which require no or little modification.

4.5.6.5 Supporting Trades and Analyses

This paragraph presents the trades and analyses which were performed leading to the selection of the recommended Habitability Subsystem design.

4.5.6.5.1 Impact of Crew Size Variation - A design requirement for the MSP is the accommodation of 5th to 95th percentile male and female crew members. This paragraph presents the results of an investigation to determine the impact of this crew size variation on dimensions and expendable needs.

Figure 4.5.6.5.1-1 shows and compares the variation in weight and height. Results show that the difference between a small 5th percentile female crew member and a large 95th percentile male crew member amounts to 97 lbs in weight

Table 4.5.6.4-1

HABITABILITY SUBSYSTEM USE OF EXISTING HARDWARE

Item	Hardware Source
Galley	Shuttle
Shower	Skylab (improved)
Hygiene Station	Skylab (improved)
Waste Management	Shuttle
Exercise and Recreation Kit	Skylab (modified)
IVA Masks	Spacelab
EMU	Shuttle
PRS	Shuttle

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Figure 4.5.6.5.1-1

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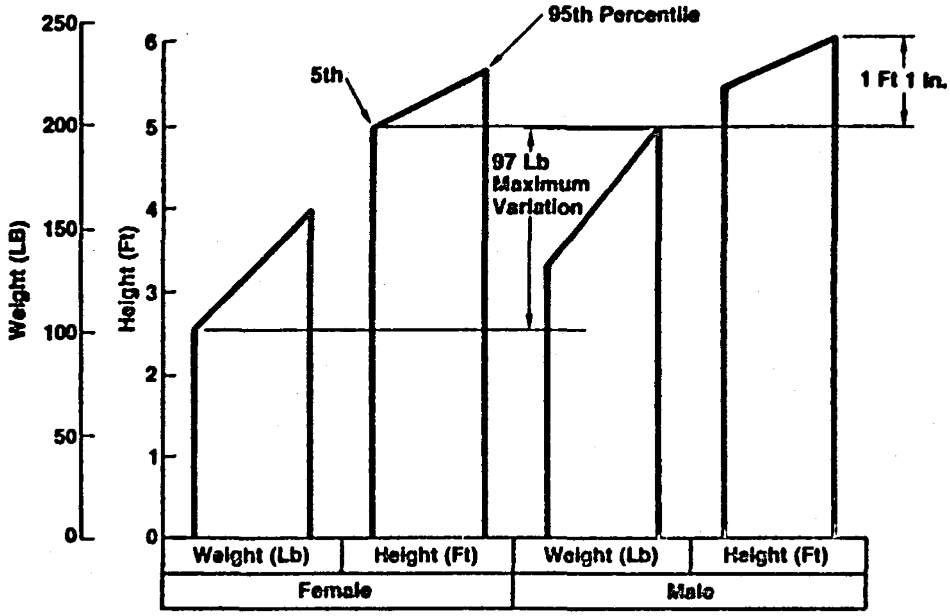
VARIATION OF CREW WEIGHT AND HEIGHT



and 1 ft, 1 inch in height. This height range and other key dimensions such as reach must be taken into account in the MSP design. Spacelab is designed for the same crew criteria but any modification to Spacelab must take into account this crew dimensional variation.

Figure 4.5.6.5.1-2 shows the variation in crew expendables as impacted by crew percentile. Caloric values for male and female crew members were taken from "Bioastronautics Data Book," (NASA SP-3006) and represents moderately active earth-based men and women. Adjustments for crew size variations were made on the basis of body weight. The resultant caloric values amount to 2954 Kcal/day average for the male crew members which is over 200 Kcal/day higher than the design diet for Orbiter and as much as 944 Kcal/day higher than actual flight data from Gemini and VOSTOK. Therefore, the data used in the figure is probably high but should be a valid representation of variation with crew characteristics.

Results show a very large variation in caloric level ranging from 1560 Kcal/day for 5th percentile female to 3534 Kcal/day for 95th percentile male. This

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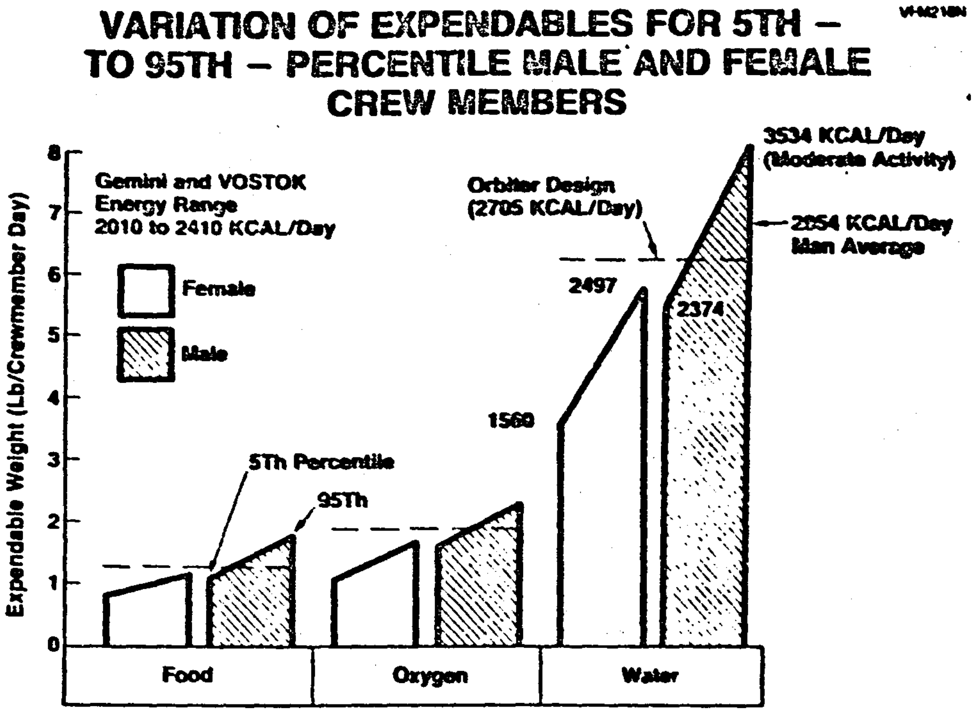
Figure 4.5.6.5.1-2



results in a variation in expendable needs of about 1 lb/day for food and oxygen and about 4 lb/day of water. This is a large variation and if not accounted for in resupplies could result in inadequate expendables available to the crew between resupplies.

The MSP expendable requirements have been based on 2800 Kcal/day which according to past data should be adequate even for an all male crew. However, consideration will have to be given to increasing expendables for a particularly large crew member or for a crew where large amounts of EVA or other strenuous activities are planned.

4.5.6.5.2 Crew Habitability -- Sleeping Accommodation - Initial definition of crew operations and requirements was established on the basis that the MSP would be a continuously manned operational space system. Thus, the study evaluation of the accommodations the crew must have for effective mission performance, was a composite of Skylab experience and other advanced manned space studies. Some of the accommodations the crew require include sleeping

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provisions, personal storage, entertainment equipment, clothing and proper restraints while dressing or sleeping.

The Skylab program has shown that in general, a unidirectional (one-g) orientation of interiors is the most habitable and perceptually adaptable approach. This approach was followed in the Spacelab program and allows for maximum utilization of existing structures and facilities in the MSP. A general adherence to a one-g orientation, however, should not prevent the utilization of the weightless environment to provide the most effective use of the interior volume such as vertical bunks, overhead storage, and multiple orientation of crew quarters.

Various interior layout and crew timeline studies have concluded that the optimum arrangement for spacecraft in the 14-foot diameter range is with the floor parallel to the longitudinal axis. This arrangement maximizes use of Spacelab interiors. As a result, the study ground rules established the Spacelab interior arrangement as baseline.

In this study we have considered crews of three and four for periods of up to 90 days with a 30-day contingency capability. The general requirements used as a basis for accommodating the sleep quarters are listed in Figure 4.5.6.5.2-1.

Various arrangements within Spacelab are conceivable. Four different approaches were studied and are shown in Figure 4.5.6.5.2-2. Of the four evaluated, Concept IV is preferred as best fulfilling the requirements.

Concept I is a center aisle approach. Sleeping restraints would be attached to extendable structure in the middle of the floor area. Although this arrangement has minimum impact on existing Spacelab hardware, it does not provide privacy and requires much effort to assemble/disassemble. As a result, the concept was rejected.

Concept II is a bunk bed concept similar to the Orbiter arrangement. The Orbiter accommodations provide 0.85 m^3 per man as opposed to the 1.92 m^3/man on Skylab. Buk-type beds in Spacelab would provide 0.94 m^3 using two experiment racks for three bunks. Access to the bunks is provided by slide in/out

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Figure 4.5.6.5.2-1

HABITABILITY MODULE — SLEEPING ACCOMMODATION CONCEPTS

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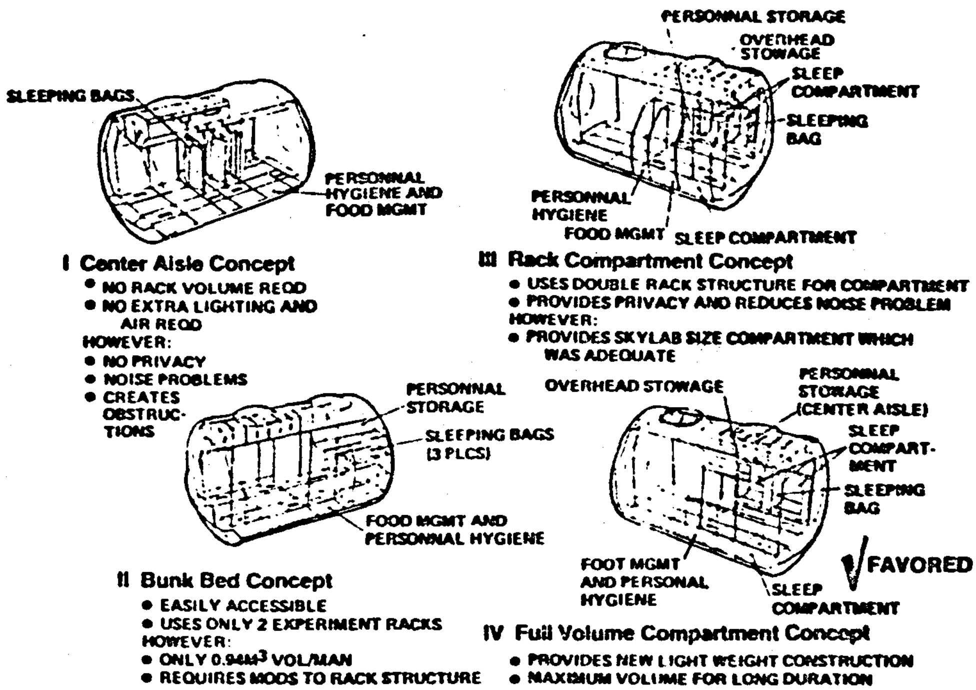

structure. This concept does not provide private quarters considered essential for long-duration space flights. In addition, personal storage would be required elsewhere in the module. As a result, this concept was rejected.

Concept III is a rack-shaped private compartment configuration. Although this concept provides private quarters approximately the size used on Skylab, the shape is less than optimum for arranging the sleep restraint plus personal equipment. Without redesigning the rack basic structural system, volume utilization is poor. Also, personal storage would be required elsewhere in the module increasing the volume required for crew support. As a result, this concept was rejected.

Concept IV is a full volume compartment concept which uses all available volume in one segment of the module for crew accommodation. The compartment, shown in Figure 4.5.6.5.2-3, is 1.34 meters long (4.4 feet) x 1.03 meters wide (3.4 feet) x 2.38 meters high (7.8 feet). The total volume is 3.3 m^3 (116.7

Figure 4.5.6.5.2-2

SLEEP QUARTERS REQUIREMENTS

- GENERAL REQUIREMENTS
  - PROVIDE PRIVATE SLEEP QUARTERS
    (MINIMUM SIZE IS 0.71 M (28") X 0.96 M (38") X 1.98 M (78") PER MAN)
  - PROVIDE STORAGE COMPARTMENT FOR EACH CREWMAN (SUITABLE FOR STOWING POCKET ITEMS, CLOTHING, BEDDING, TRASH).
  - PROVIDE ROOM FOR DONNING CLOTHING.
  - PROVIDE SOUNDPROOF AND LIGHTPROOF PADDING
    (REDUCE ACOUSTIC LEVEL WITHIN COMPARTMENT TO 22 dB).
  - PROVIDE COOLER ATMOSPHERE WITHIN SLEEP COMPARTMENT.
    (MAXIMUM SLEEP TEMPERATURE = 23.9°C)
  - PROVIDE ADJUSTABLE LIGHTING
    (45 LUMENS/M^2 MAXIMUM)
  - PROVIDE FOLD-DOWN WRITING PLATFORM WITH PENCIL, PAPER AND BOOK RESTRAINTS.
  - PROVIDE COMMUNICATION AND OFF-DUTY ENTERTAINMENT EQUIPMENT.
  - PROVIDE STOWAGE FOR TRASH IN EACH COMPARTMENT.

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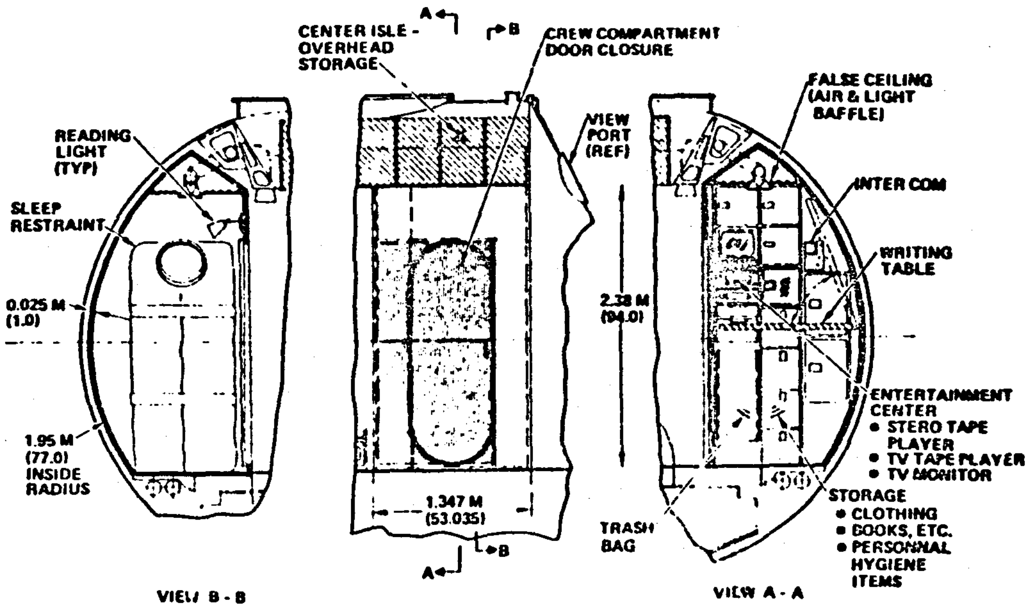
Figure 4.5.6.5.2-3
FAVORED CREW COMPARTMENT CONCEPT



cubic feet). Selection of this concept permits construction of a lightweight structure with maximum noise and odor control. Each crew compartment is private and contains a sleep constraint (Skylab type) stowage provisions for personal equipment, adjustable lighting, adjustable ventilation, communications, a writing surface, restraints plus storage for clothing, bedding and off-duty equipment, trash and entertainment provisions. This concept, with proper design, can isolate the crew from sound, odor and light and provide comfortable quarters in the long duration flight. Also, the size of the compartment makes possible temporary sleep provisions for the overlap crew during crew changeout operations.

As a result, the maximum volume concept was selected as the favored configuration for this study.

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4.5.7 Attitude Control and Stabilization

Attitude control and stabilization will be provided by the Power System. However, related analyses were performed in support of configuration synthesis. These analyses are reported on in this section.

4.5.7.1 Reference SP ACS Sizing Compatibility with MSP

An orbital disturbance moment analysis was performed to assess whether the Reference Space Platform (SP) CMG and magnetic torquer sizing was adequate for a typical Manned Space Platform (MSP) configuration. The results are preliminary because the MSP flight requirements are not well defined nor is the momentum mangement operational scheme defined knowing the operational scheme is required to define the effectiveness with which the momentum storage capacity and momentum destination capability is being used. The results defined below were generated based on certain assumptions which are also defined below.

The Reference Space Platform ACS uses three modified Skylab CMGs with a total of 9400 N-m-sec of angular momentum. The magnetic torquer system uses four electromagnets designed for the Space Telescope vehicle. Each electromagnet has a maximum of 4000 A-m^2 dipole moment capability. The torquing capability of the electromagnets is used to counteract the average disturbance torques over on orbit (bias torques). The orbital average electromagnetic torquing capability is a function of the orbit parameters (altitude, inclination, right ascension) and the scheme used to command the electromagnet dipole moment. Since the electromagnet control law was not defined, a typical capability for the electromagnets was assumed. It was assumed that the electromagnets could compensate for up to 800 N-m-sec of angular impulse per orbit.

The moment disturbances on the MSP which were analyzed were aerodynamic, gravity gradient and gyrosope (local vertical orientations). Past analyses have shown that aerodynamic moment can be significant at the orbital altitudes planned for MSP (370-435 km). The aerodynamic torque is a function of several parameters including altitude, angle between the orbit plane and the sunline (beta angle), orbit inclination, time of year (sun declination from the equator), position around the orbit (diurnal effects), vehicle configuraticn and orientation and

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solar activity. The solar activity has short- and long-term effects so past as well as current solar activity parameters are required.

Figure 4.5.7.1-1 shows the conditions of the above-mentioned parameters assumed in the disturbance analysis. Three atmospheric density conditions were assumed. The density histories were generated with the Jacchia III atmosphere model (NASA SP-8021, March 1973) with the solar activity parameter values shown on Table 4.5.7.1-1. The values generate a medium, a high and a worst-case atmospheric density history. The solar activity tends to follow an 11-year cycle so the probability of conditions occurring depends on the year of flight. The "COMMENTS" column of Table 4.5.7.1-1 gives some information about the probability of occurrence.

The MSP configuration chosen in the analysis is shown on Figure 4.5.7.1-1. The solar array size corresponds to a 25 kW electrical power capability to the payloads. The Space Platform payload modules include a habitability/payload module (opposite end from solar arrays), an airlock adapter (connects modules

Figure 4.5.7.1-1

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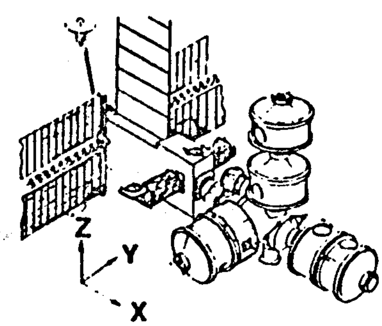
REFERENCE SP ACS SIZING ANALYSIS

Reference Space Platform (25 kW)
- **Three Modified Skylab CMGs**
- **Four Space Telescope Magnetic Torquers**



Conditions Analyzed
- **200 and 235 nmi Altitudes**
- **0, 40, and 80 deg β-Angles**
- **57.5-deg Inclination**
- **Medium, High, and Worst-Case Atmospheric Densities**
- **June 21 — Time of Year**
- **Five Inertial Orientations**
- **Two Local Vertical Orientations**

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Table 4.5.7.1-1

SOLAR ACTIVITY PARAMETER VALUES

JACCHIA III ATMOSPHERE MODEL*

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Condition	$\overline{F10.7}$	F10.7	Ap	Comment
Medium	145	200	17	2σ Values for 1989
High	230	315	35	2σ Values for 1991
Worst Case	230	315	400	Short Term Peak Values for 1991

*NASA SP-8021, March 1973

to Reference SP), a logistics module (left side), a Life Science research laboratory (second from top). The mass properties are shown on Table 4.5.7.1-2. Aerodynamically, the vehicle was modeled as three fixed, mutually perpendicular flat plates with a fourth gimballed flat plate representing the solar array. Table 4.5.7.1-3 defines the areas and center of pressures of the four flat plates. The aerodynamic forces were generated using a free molecular flow model with a degree of diffuse reflection incident-particle emission.

The results of the MSP external disturbance analysis are shown in Figures 4.5.7.1-2, -3 and -4. The results are in terms of how long an orientation can be maintained without saturating the CMG momentum capability. (Note that the orientation limitations are due to momentum considerations only and do not reflect other limiting factors such as heat rejection or electrical power.) Some assumptions regarding margins required had to be made to generate the orientation hold capabilities value shown in the figures. The approach was different for the following types of orientations.

Type 1 - inertial with an axis perpendicular-to-the-orbit-plane (POP)
Type 2 - inertial with the Z-axis parallel-to-the-sunline (PSL)
Type 3 - local vertical

TABLE 4.5.7.1-2

MSP MASS PROPERTIES

(ACS SIZING ANALYSIS)

MASS (Kg)	CENTER OF MASS* (M)	MOMENTS-OF-INERTIA ($Kg\text{-}M^2$)
42800	$X_{CG} = 13.17$	$I_{XX} = 1.4374 \times 10^6$, $I_{YZ} = -79276$
	$Y_{CG} = -1.02$	$I_{YY} = 2.0554 \times 10^6$, $I_{ZX} = -101792$
	$Z_{CG} = 16.64$	$I_{ZZ} = 2.5172 \times 10^6$, $I_{XY} = 35855$

*COORDINATE SYSTEM REFERENCE POINT

CENTER OF SOLAR ARRAY GIMBAL: X = 0.15 M
Y = 0 M
Z = 14.72 M

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TABLE 4.5.7.1-3
MSP FLAT PLATE AERO MODEL
(ACS SIZING ANALYSIS)

PLANE	AREA(M^2)	CENTER OF PRESSURE*(M) X	Y	Z
XY	95.5	13.56	-1.49	15.15
XZ	178.2	9.66	0	24.48
YZ	74.9	15.18	-1.92	18.56
GIMBALLED ABOUT Y-AXIS	697.7	0.15	0	14.72

*COORDINATE SYSTEM REFERENCE POINT

CENTER OF SOLAR ARRAY GIMBAL: X = 0.15 M
Y = 0 M
Z = 14.72 M

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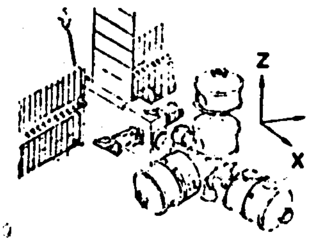

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REFERENCE 25 KW PS ACS ORIENTATION HOLD CAPABILITY FOR MSP

Medium Atmospheric Density

Principal Axes Orientation	β (deg)	Orientation Hold Duration (Orbits)					
		235 nmi			200 nmi		
		0	40	80	0	40	80
XPOP-YPSL		∞	∞	∞	∞	∞	∞
XPOP-ZPSL		∞	∞	∞	∞	∞	∞
YPOP-ZPSL		120	∞	∞	4	550	∞
ZPOP-YPSL		44	∞	∞	3	∞	∞
ZSI-XIOP		∞	3	26	8	2	13
ZLV-XPOP (YVV)		12	16	15	2	2	2
ZLV-YPOP (XVV)		∞	∞	∞	∞	∞	∞

Three Skylab CMGs and Four Space Telescope Electromagnets

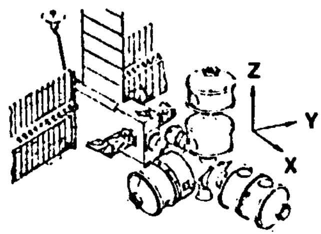

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Figure 4.5.7.1-3

REFERENCE 25 KW PS ACS ORIENTATION HOLD CAPABILITY FOR MSP

High Atmospheric Density

Principal Axes Orientation	β (deg)	Orientation Hold Duration (Orbits)					
		235 nmi			200 nmi		
		0	40	80	0	40	80
XPOP-YPSL		∞	∞	∞	<1	∞	∞
XPOP-ZPSL		∞	∞	∞	<1	∞	∞
YPOP-ZPSL		5	∞	∞	1	5	∞
ZPOP-YPSL		4	∞	∞	<1	23	∞
ZSI-XIOP		16	2	15	<1	1	7
ZLV-XPOP (YVV)		2	2	2	<1	<1	<1
ZLV-YPOP (XVV)		∞	∞	∞	29	31	23

Three Skylab CMGs and Four Space Telescope Electromagnets

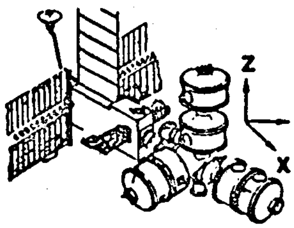

Figure 4.5.7.1-4

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REFERENCE 25 KW PS ACS ORIENTATION HOLD CAPABILITY FOR MSP

Worst-Case Atmospheric Density

Principal Axes Orientation	β (deg)	Orientation Hold Duration (Orbits) 235 nmi			200 nmi		
		0	40	80	0	40	80
XPOP-YPSL		∞	∞	∞	<1	<1	∞
XPOP-ZPSL		∞	∞	∞	<1	∞	∞
YPOP-ZPSL		3	∞	∞	<1	<1	<1
ZPOP-YPSL		2	∞	∞	<1	13	∞
ZSI-XIOP		5	1	13	<1	<1	7
ZLV-XPOP (YVV)		1	1	1	<1	<1	<1
ZLV-YPOP (XVV)		∞	∞	∞	8	8	7

Three Skylab CMGs and Four Space Telescope Electromagnets

In all cases, a 25 percent CMG momentum margin was maintained (i.e., it was assumed that only 0.75 x 9400 = 7050 N-m-sec of momentum storage capability could be utilized). The cyclic momentum was assumed absorbed by the CMGs and any CMG momentum above the cyclic requirement was used to absorb bias momentum that the electromagnets could not compensate for. It was assumed that the cyclic momentum was centered (preconditioned) so that the plus and minus peaks were of equal magnitude. The centering was done for each momentum vector component.

The hold duration was calculated using the following equation:

$$T_{hold} = \frac{(0.75)(9400) - H_{cyclic}}{(Bias - 800)}$$

where, H_{cyclic} = peak magnitude of the centered cyclic momentum

$$Bias = \begin{cases} \text{POP bias momentum (Type 1 orientations)} \\ \text{Total bias momentum (Type 2 orientations)} \\ \text{Total bias momentum (Type 3 orientations)} \end{cases}$$

T_{hold} = Number of orbits the orientation can be held before the CMGs reach 75% saturation.

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The total bias momentum requirement was not used for Type 1 orientations because it was assumed that the vehicle could be tilted so that gravity gradient and aero-induced IOP biases could be cancelled. This is not always the case and further analysis is required to define the potential momentum management benefits from tilting (including local vertical orientations) and the potential impact tilting has on other functions such as heat rejection, electrical power generation and payload operations. Note that the orientation definitions shown on Figures 4.5.7.1-2, -3 and -4 refer to the principal axes, not vehicle geometric or structural axes.

In the equation, "T_{hold}" was assumed infinity if "Bias" was less than 800 N-m-sec and H_{cyclic} was less than (0.75)(9400). "T_{hold}" was considered less than one orbit when "H_{cyclic}" exceeded (0.75)(9400) = 7050 N-m-sec or when (Bias - 800) >[(0.75)(9400) - H_{cyclic}].

Figure 4.5.7.1-5 summarizes the analysis conclusions. The Reference Space Platform ACS design of three Skylab CMGs and four Space Telescope electromagnets

Figure 4.5.7.1-5

VF0721

MSP/SPACE PLATFORM ACS CAPABILITY SUMMARY

- Reference SP ACS Adequate For Many MSP Operations
- XPOP-YPSL Orientation Best Suited For Long-Term, High-Power Operations
- ZLV-YPOP Orientation Is Acceptable For Low β-Angle Operations
- Orientation Restrictions For Low Altitudes and High and Worst-Case Atmosphere Conditions
- Additional CMGs and Electromagnets Desirable To Increase Orientation Flexibility and Margins For Uncertainties, Failures and Maneuvers
- Other Subsystem and Payload Requirements Also Impact Orientation Hold-Duration Capabilities

will allow operations of the MSP configuration studied. Operations will be restricted at times with respect to orientation hold duration especially at lower altitudes and higher atmospheric densities. The XPOP-YPSL orientation is relatively easy to control and is desirable for a number of reasons including good electrical power, heat rejection and payload viewing capabilities. The ZLV-YPOP(XVV) local vertical orientation is also relatively easy to control, but electrical power capabilities degrade approximately as the cosine of orbit β-angle and may only be useful for low β-angle orbits. The other local vertical orientation (ZLV-XPOP) has good electrical power and heat rejection at high β-angles but is relatively hard to control because of the large thermal radiator-induced aero torques.

It should be noted that at 235 nmi altitude, all orientations studied can be held for at least one orbit and usually much more. Additional momentum control capability may be desirable, however, if a good orientation selection is required at lower altitudes. Also, additional momentum control capability may be desirable to maximize operational capability in the vent a CMG or electromagnet fails. The loss of one CMG out of three has more operational impact than a 33% mementum storage capacity loss because of CMG gimbal rate requirements near the zero momentum state. If the CMG gimbal rate capability is exceeded, the whole vehicle attitude is "jolted" which may not be acceptable to some payloads.

The orientation hold duration data shown on Figures 4.5.7.1-2, -3 and -4 reflect ACS capabilities. As noted above, other subsystem and payload requirements also must be considered when generating flight operational plans.

4.5.7.2 Man Disturbance Analyses

The presence of men on the Space Platform will result in spacecraft motion disturbances. The motions result from forces applied to the vehicle when the men move themselves relative to the vehicle. Fine pointing and low-g payload operations may be impacted by the spacecraft motions and a simplified analysis of the man-induced motions was performed to evaluate potential problems.

The vehicle configuration shown in Figure 4.5.7.2-1 was used for the motion disturbance analysis. The mathematical model assumed a rigid vehicle except

Figure 4.5.7.2-1

MAN DISTURBANCE ANALYSIS

(12.5 kW PS)

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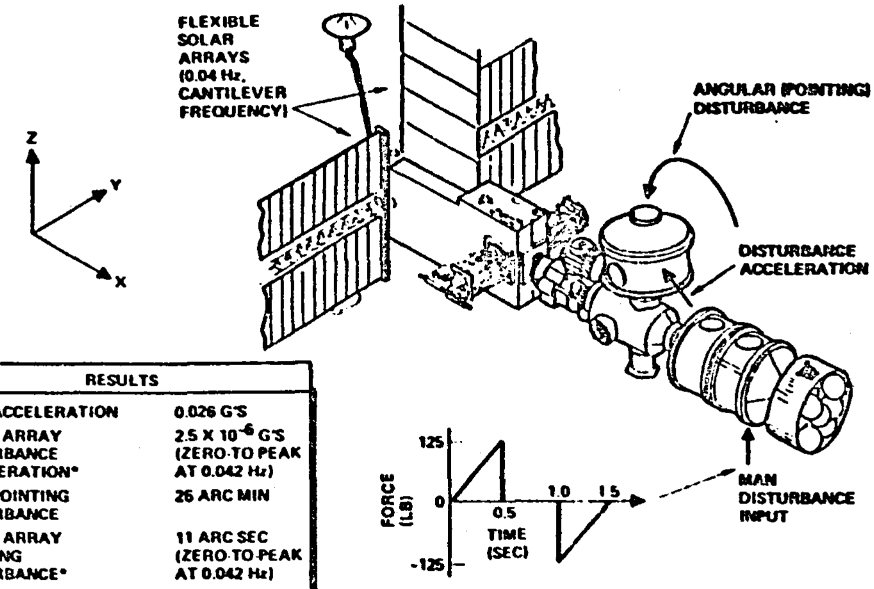

RESULTS	
PEAK ACCELERATION	0.026 G'S
SOLAR ARRAY DISTURBANCE ACCELERATION*	2.5×10^{-6} G'S (ZERO-TO-PEAK AT 0.042 Hz)
PEAK POINTING DISTURBANCE	26 ARC MIN
SOLAR ARRAY POINTING DISTURBANCE*	11 ARC SEC (ZERO-TO-PEAK AT 0.042 Hz)

*ASSUMES LOW BANDWIDTH PS ACS

for the solar arrays which were assumed to have a cantilever frequency of 0.04 Hz. The man-generated force was input in the Z-direction at the aft (+X) end of the habitability module (see Figure 4.5.7.2-1). The linear acceleration at the top (+Z) end of the payload module (+Z-axis mounted module) was calculated as an indicator of the potential impact to payloads requiring a low-g environment. Also, the angular displacement of the vehicle was calculated to define potential impacts to pointing payloads.

The man-generated force history represented a lateral translation of the astronaut from one wall of the habitability module to the other. The assumed force history is shon on Figure 4.5.7.2-1 and reaches a relatively high value though easily achievable by an astronaut. It was assumed that the Space Platform attitude control system was low bandwith relative to the dynamics of interest and would not affect the motions at 0.04 Hz and above and was not modeled. Similarly, the solar array mass was not included during the disturbance application time because of the solar array's low frequency relative to the 1.5 sec force input duration. After the disturbance input was over, the solar array dynamics were included to define solar array low frequency vibration effects.

The acceleration and pointing disturbances are summarized on Figure 4.5.7.2-1. Two values are given for both acceleration and pointing disturbances. One value corresponds to the peak value which occurs during the disturbance application period (1.5 sec) and the second corresponds to the residual motion after the disturbance is over. The residual motion is sinusoidal and is caused by the solar array flexibility and will slowly damp out due to attitude control system and mechanical damping effects. No damping was included for this analysis. The results show that the peak accelerations and pointing disturbances occur during the 1.5 sec disturbance input. After the disturbance is removed, the residual solar array-induced motions are relatively small. It should be noted that the peak values are rigid vehicle results and a vehicle the size of the Space Platform will likely have vibration frequencies (other than the solar array frequency modeled) which are energized with the man disturbances and so affect the peak values.

The peak values shown would be significant to many payloads. Typically, low-g payloads require a maximum of 10^{-5} to 10^{-3} g accelerations which are well below the 0.026 g calculated. The residual solar array-induced accelerations would be acceptable to most payloads. The peak pointing disturbance of almost a half a degree is unacceptable to many paylods if mounted directly to the platform. If an auxiliary pointing system is used, the pointing disturbance seen by the payload would be less than the platform motion. An auxiliary pointing system performance is degraded primarily by linear accelerations rather than angular motions. As with Orbiter-mounted payloads, the man disturbances would likely be a problem for payloads requiring very fine pointing even when an auxiliary pointing mount is used.

4.6 INTERFACE DEFINITION

This paragraph describes interfaces between the MSP and the Orbiter and Space Platform and between the major MSP elements, shown schematically in Figure 4.6-1. Figure 4.6-2 summarizes the interfaces between major MSP elements for each utility. Figure 4.6-3 gives a design for physically performing the interface at the berthing port. The descriptions below will include physical

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Figure 4.6-1 VFL 842
INTRA-SYSTEM INTERFACES

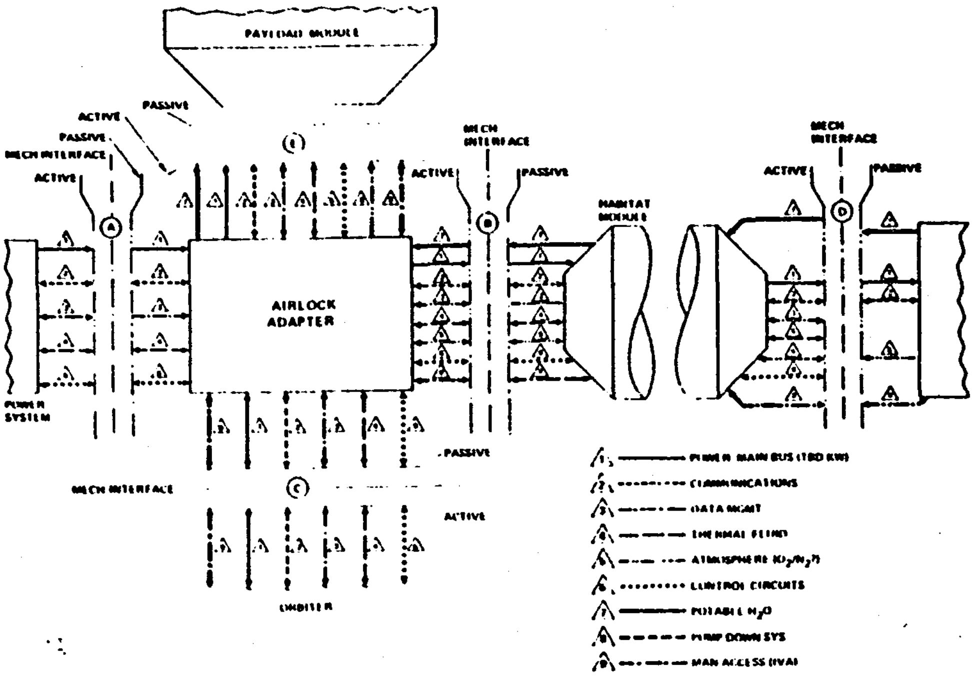

Figure 4.6-1 (continued) VFL843
INTRA-SYSTEM INTERFACES

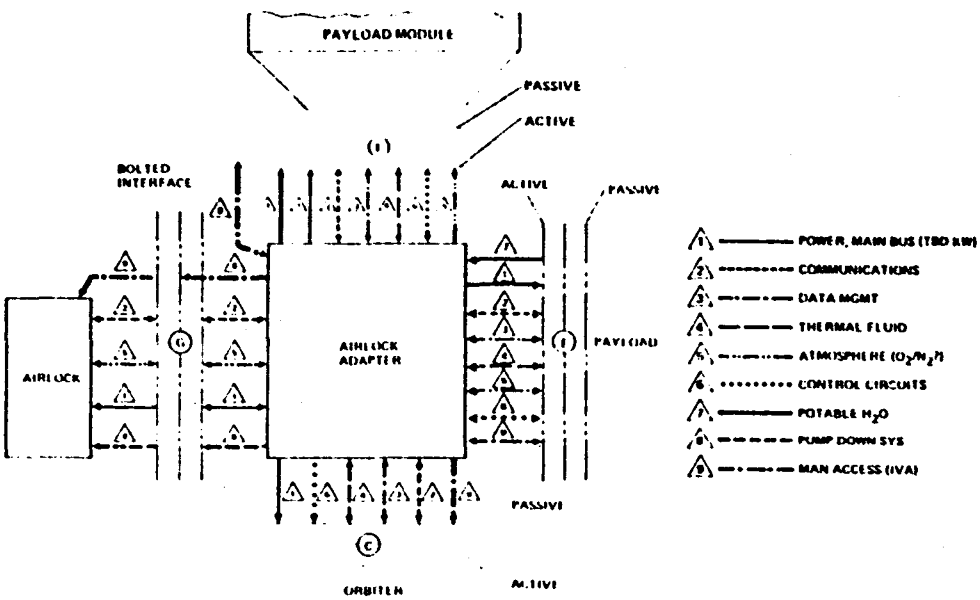

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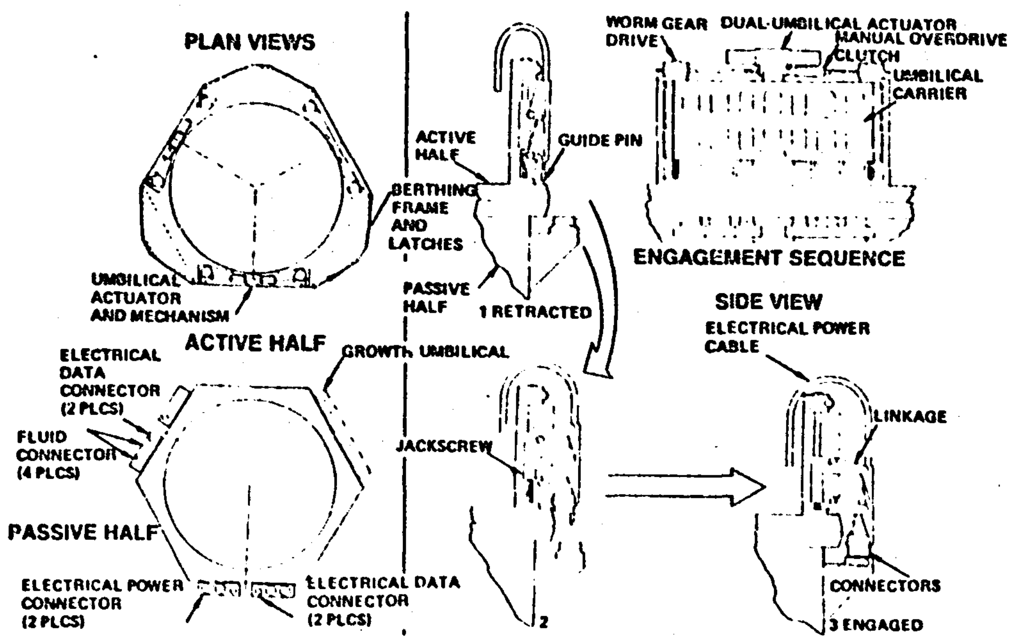
Figure 4.6-2 VFM332N

BASIC CONFIGURATION INTERFACES

Utility / Interface	Airlock Adapter-Payload Module	Airlock Adapter-Power System	Airlock Adapter-Orbiter	Airlock Adapter-Habitability Module	Airlock Adapter-Airlock	Habitability Module - Aft Port	Airlock Adapter-Logistics Module
Power, Main Bus	0	0	0	0	0	0	0
Communications	0	0	0	0	0	0	0
Data Management	0	0	0	0		0	
Thermal Fluid	0	0		0	0	0	
Atmosphere (N_2 and O_2)				0	0	0	0
Control Circuits	0	0	0	0	0	0	0
Potable H_2O	0			0		0	0
Pump Down System					0		
Man Access (IVA)	0		0	0	0	0	0
Atmosphere Interchange (RCS)	0						0

Figure 4.6-3 V10583

BERTHING UMBILICAL INTERFACE



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descriptions, performance requirements and operations considerations. Detailed description of the mechanical design of the interfaces are contained in Paragraph 4.5 under mechanical design of the berthing umbilical interface.

4.6.1 Environmental Control and Life Support

Interfaces defined in the ECLSS area include thermal fluid (water), atmosphere (O_2/N_2), potable and waste water and pumpdown system (air). Thermal fluid lines will exist between the MSP and the Space Platform and between MSP elements except the Logistics Module. The thermal fluid lines are expected to be between 1/2 and 3/4 inch diameter stainless steel tube of thin wall (0.16 inch) because of the low anticipated pressures of less than 1 atmosphere.

Atmosphere O_2 and N_2 is normally supplied from the Logistics Module and all other MSP modules via the Airlock/Adapter. These will be small diameter stainless steel lines (1/4 inch diameter) which will normally operate at 215 psid. This relatively low distribution pressure is made possible by placing the high pressure regulators from the Spacelab O_2/N_2 Panel and locating them at the O_2 and N_2 tank outlets in the Logistics Module.

Atmosphere interchange is also planned to the Logistics Module and Payload Modules for humidity and carbon dioxide control. This will be a manually installed duct of about three inch diameter.

There will also be some natural interchange between modules and between the MSP and Orbiter during open hatch operation. This will result in some atmosphere interchange by diffusion and air circulation caused by crew movement and forced circulation within the modules.

Potable water and waste water interfaces exist between the Logistics Module, Airlock/Adapter, Habitability Modules and some Payload Modules. The waste water interface from Payload Modules will handle only condensate water. Flow rates will be low allowing for small 1/4 to 3/8 inch low pressure lines. The lines will be stainless steel because of the corrosive nature of water.

Incorporation of an airlock pumpdown system results in an interface between the Airlock and the Airlock/Adapter to accept pumpdown air. The air will either be pumped directly into the cabin thereby causing a slight variation in cabin pressure or a receiver mounted on the Airlock/Adapter exterior.

4.6.2 CDMS Interfaces

The CDMS has interface circuits at all the module interfaces to allow the subsystem to expand and adapt in an integrated fashion as the platform configuration evolves. For the interface with the Orbiter, the emphasis is on being compatible with standard Orbiter data and communication service so that Orbiter modification requirements are kept to a minimum. This interface includes a data bus for the exchange of data between the Orbiter and the platform, voice communication channels, timing distribution circuits, video data circuits and caution and warning (C&W) control and monitor circuits.

The interface between the Airlock/Adapter and the Space Platform will be functionally similar to the Orbiter interface. Data bus, timing signal and C&W circuits will be provided, as well as high data rate channels to provide a path to the Space Platform Ku-band communications equipment. Voice and video data will be conditioned in the Airlock/Adapter to be compatible with the digital data channels of the Power System. The data bus and C&W hardwire circuits will provide the crew with Power System status data and a capability to control the Power System.

The remaining interfaces (Airlock/Adapter to Payload Module, Airlock/Adapter to Habitat Module, Airlock/Adapter to Logistics Module, etc.) will be standardized as to interface connectors, pin assignments, signal design and function so that overall platform configuration flexibility and growth capability to transfer data bus signals, voice, video data, timing signals and C&W signals. Unique circuit assignments, if required, can be accommodated with an interface circuit switching matrix within one of the modules.

An important provision of the interface design is the isolation capability. Circuit isolation is necessary and will be provided to ensure that critical hardware is protected from damage during demated modes and during mating and demating operations. The necessary isolation will be provided with isolation amplifiers and/or deadfacing switches.

The CDMS interface functions will be carried in twisted shielded pairs arranged in two or more connectors at each interface. It is estimated that 60 pairs per interface will provide the required interface functions with ample spares.

4.6.3 Electrical

Manned Space Platform main power is provided by the Space Platform at a nominal 30 VDC via a three-bus interface with the Airlock/Adapter. The bus system handles the rated interface power of 25 kW average and 35.5 kW peak. The three buses are routed to the 30 VDC Power Distributor in the Airlock/Adapter for distribution to platform subsystem/users in the core modules, payload modules and payload pallets. In addition, a three-bus interface is provided for the Orbiter at the A/A -Z port. Two buses are used for the payload interfaces, with growth provisions for a third. Power is transferred across interfaces via connectors on the standard berthing umbilical interface mechanism (on the active side) mating with connectors attached to structure on the passive side. Main bus interfaces are shown in Figure 4.6-1. In addition to main bus power, emergency power (not shown) is distributed from the A/A to all interfaces except the Orbiter.

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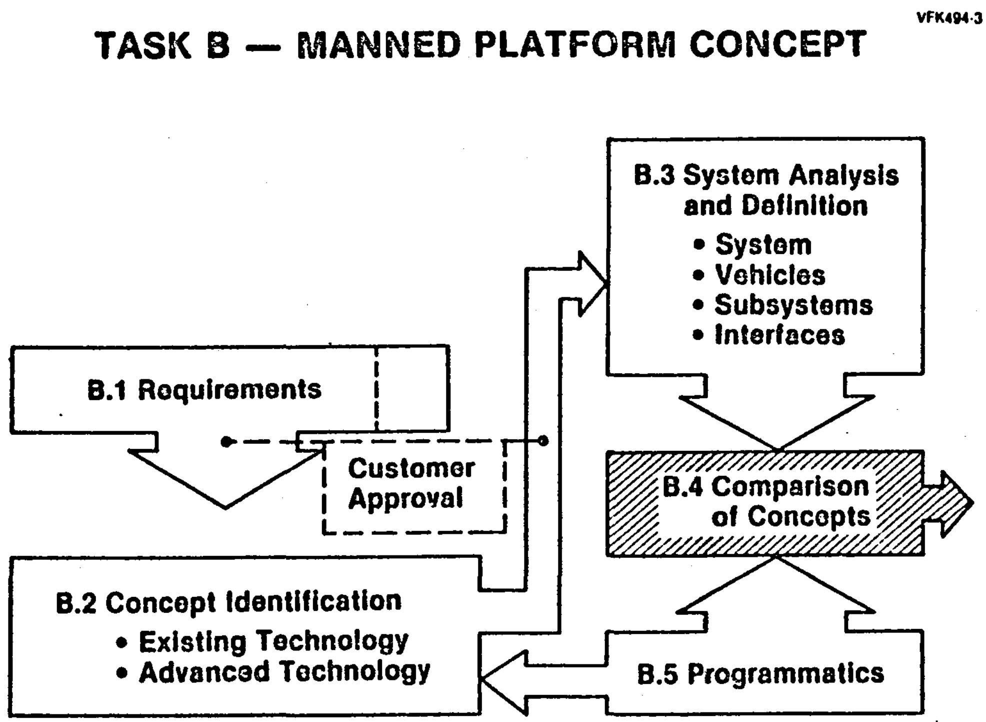
Section 5
COMPARISON OF CONCEPTS (SUBTASK B.4)

In this subtask, the two configurations studied in detail in the previous task (B.3) were compared and one selected for recommendation as a conclusion of the study. Figure 5-1 illustrates the relationship of this subtask to others in the study.

Figure 5-1



Concepts 1 and 2 represented markedly different, but individual, logical approaches to fulfilling identifiable Manned Platform system and payload requirements.

Since both approaches were conceived and developed to perform the same habitation, payload and logistics functions and to interface with the Space Platform continually and the Shuttle periodically, their overall configuration effectiveness was judged to be roughly equivalent. However, since the modules which fulfilled a

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given function in each configuration were quite different, the comparison described here was conducted on a modular level. Nevertheless, a judgment was made relative to the intra-configuration level effectiveness of each module, namely how it interfaced with other modules and those functions which they shared.

The broad level of detailed definition of these two approaches, at the exact time in the study where the task was performed, permitted only a broad-view evaluation, but this circumstance was offset by the value-leverage of our group evaluation process. Team members from all disciplines and persuasions, and extensive experience in Space Station studies and Skylab contributed to the evaluation, lending considerable qualification to the grading and selection.

The criteria applied in this comparison was selected to broadly cover all aspects of major programmatic and operational significance. They were as follows:

- Cost Effectiveness
- Mission Effectiveness
- Safety
- Development Requirements
- Schedule Risk
- Operational Complexities
- Growth Potential

The seven criteria were treated as if equal-weighted since they would, in fact, all be of major importance in a program, albeit at different times and from the differing views of various segments of the managerial structure of NASA and the producing contractors.

Presented next is a summarization of the considerations which led to the grades given per module for each of the seven criteria, as shown in Figure 5-2.

Cost Effectiveness

Concept 1 was judged to cost less than Concept 4 since the rack-tunnel approach to the adapter and logistics module was definitely simpler than the rack-spacious-chamber approach of Concept 4. This was offset by the substantially

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Figure 5-2

COMPARISON OF CONCEPTS (A, B OR C; A IS BEST)

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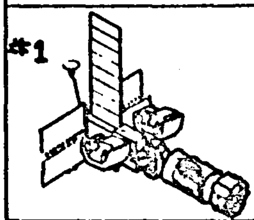
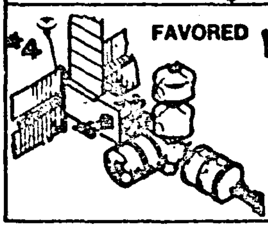
Concept		Criteria / Features	Cost Effectiveness	Mission Effectiveness	Safety	Development Reqts	Sked Risk	Op's Complex	Growth Potent.
#1 		■ Rack Adapter	A	C	C	B	B	B	C
		■ 3 Segment Modules	C	B	N/A	C	C	B	B
		■ Rack Logistics	A	C	C	A	A	A	C
	B-	Rating	B+	C+	C	B	B	B+	C+
#4 FAVORED ✓ 		■ Rack/Haven Adapter	B	A	A	C	C	C	A
		■ 2 Segment Modules	A	A	N/A	B	B	B	A
		■ Rack/Segment Logistics	B	A	A	[illegible]	B	B	B
	B+	Rating	A-	A	A	B-	B-	B-	A-

lower cost of a slightly (subsystem) modified two-segment module (habitat) of Concept 4 as opposed to the heavily-modified (major added structure + subsystems) of Concept 1. Conclusion: Concept 4 slightly less costly than Concept 1.

Mission Effectiveness

Due to the restrictions of the rack-tunnel approach of Concept 1 in operations such as early central control, safe haven, inter-module transfer and outhouse (out of habitat) waste management, Concept 4 was graded much higher. Conclusion: Concept 4 much more mission-effective than Concept 1.

Safety

For much the same reasons given for mission effectiveness, the overall prospect of crew safety under routine and contingency situations, Concept 1 was graded less than Concept 4. Conclusion: Concept 4 would be safer than Concept 1.

Development Requirements

Here the added complexities of Concept 4's better performance of mission requirements than Concept 1, presented a less challenging development prospect for the

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latter, but only slightly so because of the considerable challenge of incorporating an added segment to the two-segment, standard Spacelab. Conclusion: Concept 1 would be slightly less of a development challenge than Concept 4.

Schedule Risk

Grading for this criteria paralleled that of development requirements and is significant as a separately judgeable criteria because of the serious impacts of delays in vehicle development on payload and support function developments, and thus growth of costs in "out-of-basic-vehicle-programs." Conclusion: There is a slightly greater schedule risk inherent in the more complex (but broader capability) Concept 4 as opposed to the Concept 1.

Operations Complexities

The adapter of Concept 1 is designed to add very basic manned access and supply provisions to the Space Platform to which their manned habitat and payload modules may be added. The Concept 4 adapter provides such basic capabilities plus a mini-control center, an EVA airlock, waste management, repair kits, multiple berths and considerable volume for internal passage and long-subsistence times in case of emergency.

These features provide considerable benefits and flexibilities, but at the expense of extra operational complexity. The habitats (three- and two-segment modules for Concept 1 and Concept 4, respectively) were judged identical in operational complexity since there are only capacity differences. The rack-logistics module of Concept 1 was rated more desirable from an operational complexity standpoint since it did effectively provide the basic functions needed. The added pressurized volume of Concept 4 involved slightly more complex equipments internally. Also, due to its size (length), it creates some operational constraints in initial berthing and thereafter, some restrictions in reach-around, access for future buildup. Another Concept 1 variation to be considered (a sort of comparative benefit) is one wherein logistics items could be stored for ascent/descent in the Orbiter cockpit/lower floor or in an up/down stowage module in the cargo bay. Conclusion: Concept 4 (although desired over 1 in general) did have complexity that could, in a very low-cost approach, be postponed, in favor of early use of Concept 1 and variants thereof.

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Growth Potential

Although Concept 1 would provide a significant basic capability for the conduct of internal and external payload activities, it is relatively restricted as to efficient growth potential. First of all, the elemental services nature of the Concept 1 rack adapter does not offer the flexibility and habitat/payload module interconnect and optional escape route/haven features that Concept 4 has. Secondly, the three-segment Spacelab module is considered unwieldy for accommodating the numerous payload functions wherein a dedicated, two-segment unit would suffice and be preferred by payload-function-cramming-avoidance interests. Lastly, the greater internal volume of the Concept 4 logistics module provides considerable flexibility for supporting growth in (1) small increments by offering volume for (a) extra crew quarters on a bivouac basis and (b) smaller dedicated internal payload installations and (2) support of large increments of growth by providing in one unit a combined facility for added crew quarters and the complete sustenance for same for 180 days, permitting replication for packaged crew increases in three-man increments, or six with end-to-end berthing. Conclusion: Concept 4 has much greater growth potential than Concept 1.

Therefore, in view of the above rationale, Concept 4 is recommended as a conclusion of this study, and a brief resume of details thereon is presented next in the following section (Section 6).

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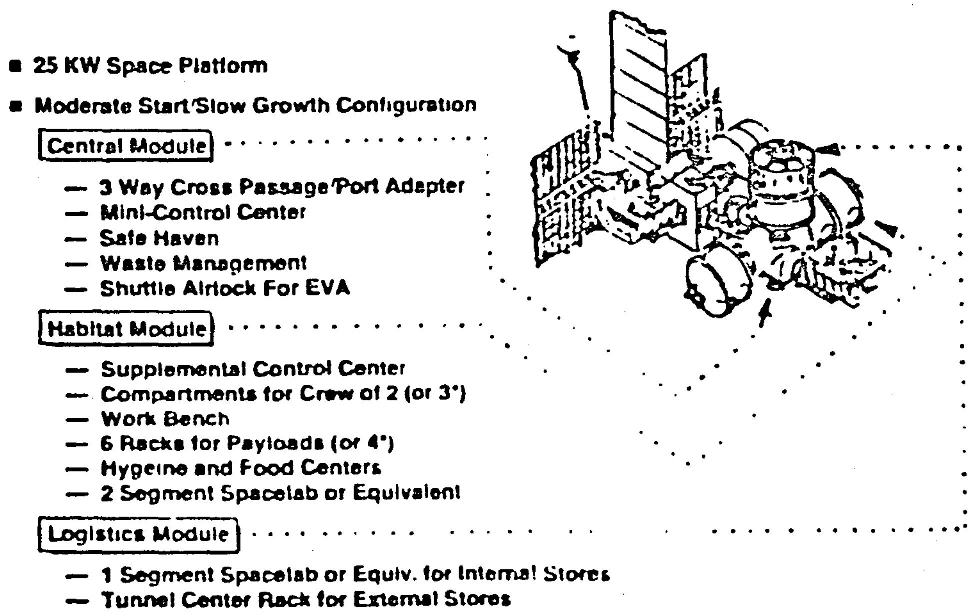
Section 6
RECOMMENDED CONCEPT FOR MANNED PLATFORM

The basic configuration recommended, shown in Figure 6-1, incorporates a 25 kW Space Platform berthed in-line to a pressurized central (adapter/haven) module with a two-segment Spacelab-type habitat and a pressurized logistics module attached radially. It provides accommodations for a crew of two to four for 180 days, exterior and interior payload accommodations, with significant use of existing hardware and much potential for future growth.

Figure 6-1
RECOMMENDED CONCEPT FOR
MANNED PLATFORM



The 25 kW Space Platform provides power, heat rejection, communication/data management and attitude stabilization. Provisions include accommodation for exterior palletized payloads as well as interior pressurized payload modules. The viewing payloads can be berthed to the Space Platform Y-ports directly or to a truss beam relocated to the aft (X) port of the central adapter from its original position on the 25 kW Space Platform. This latter beam provides necessary rotation for continual earth tracking.

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6.1 OVERALL CONFIGURATION

This configuration is composed of a 25 kW Space Platform, a central (adapter/haven) module, a two-segment habitability module, and a logistics module. End-berthing accommodations are provided for all modules and radial-berthing is provided on the central module, as shown assembled in Figure 6.1-1 and exploded in Figure 6.1-2.

The Space Platform (SP) is the MSFC referenced "Power System" configuration defined in NASA document PM-001, dated September 1979, with rotating payload port extensions defined in MDAC document MDC G9246, dated October 1980, "Conceptual Design Study of a Science and Applications Space Platform."

Figure 6.1-1
RECOMMENDED MANNED PLATFORM

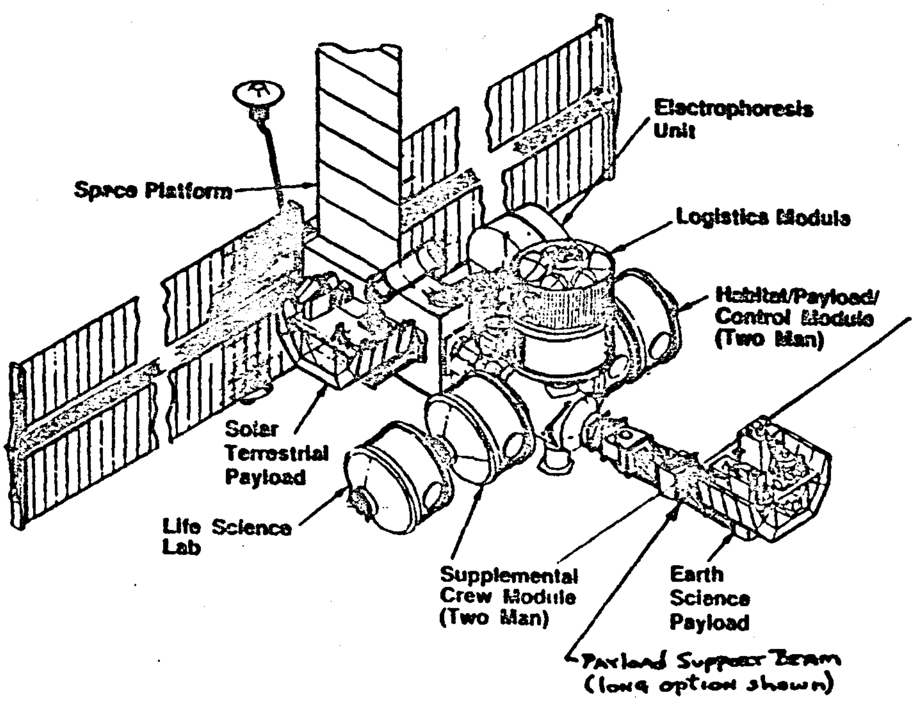

Figure 6.1-2

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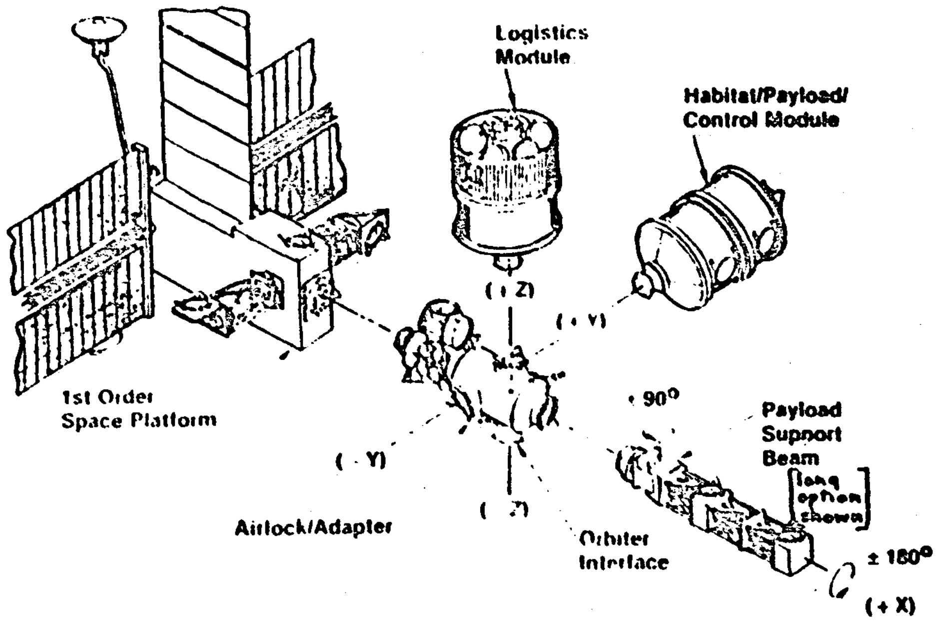
BASIC MANNED PLATFORM ELEMENTS



The SP, by definition, is required to supply power, heat rejection and communication/data management resources to attached payloads. In addition, the SP will provide attitude stabilization to the entire orbiting assembly.

Figures 6.1-3 and 6.1-4 illustrate the build-up sequence inherent in the recommended concept with options for increases in crew size or payloads or both.

6.2 CENTRAL MODULE (ADAPTER/HAVEN)

During the concept formulation phase, it was determined that this module was to be a very key element in the activation, build up and sustenance of the Manned Space Platform. The favored central module configuration is shown in Figure 6.2-1. The module is a 4.33M dia x 8.12M long structural element configured to provide the structural interface between the Orbiter and Power System plus four (4) pressurized modules. Since the general arrangement and module

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Figure 6.1-3

INITIAL OPERATIONAL LAUNCH SEQUENCE

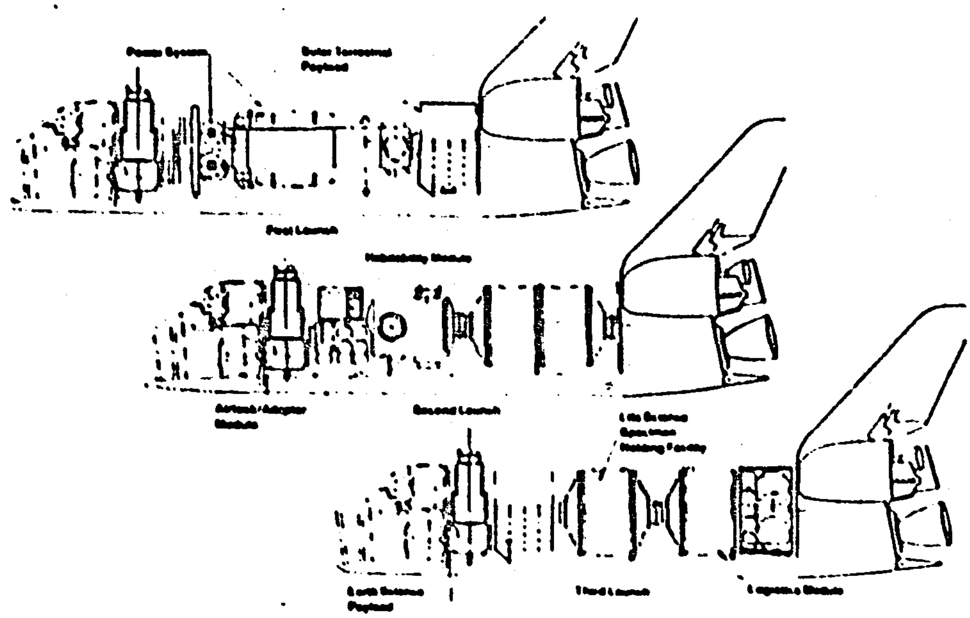

Figure 6.1-4

MANNED PLATFORM BUILDUP

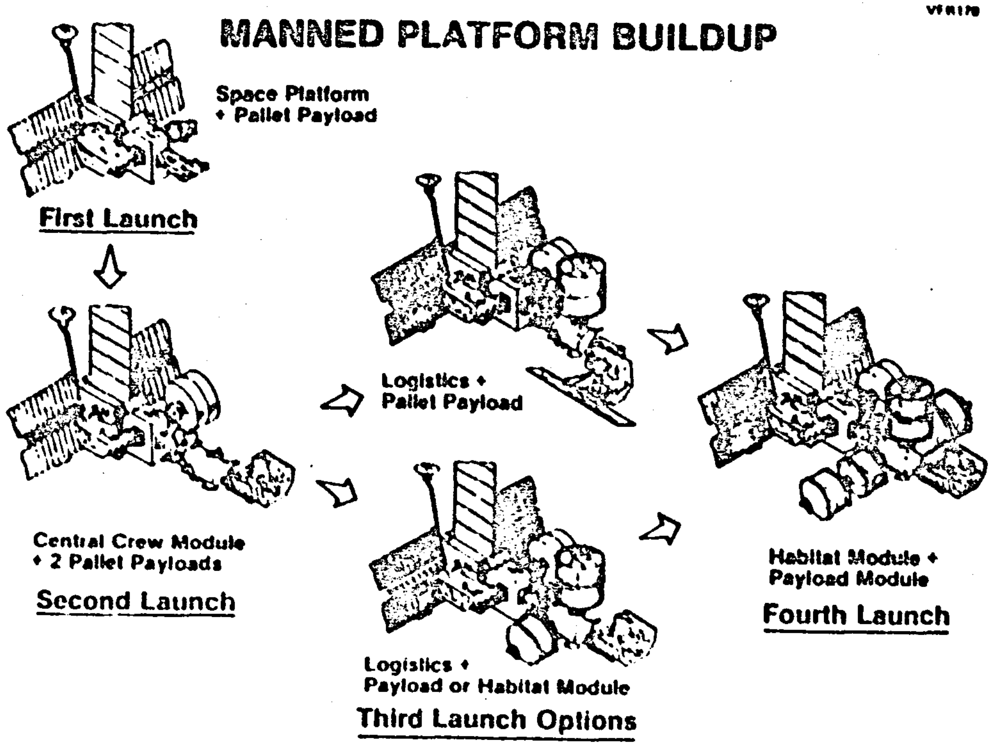

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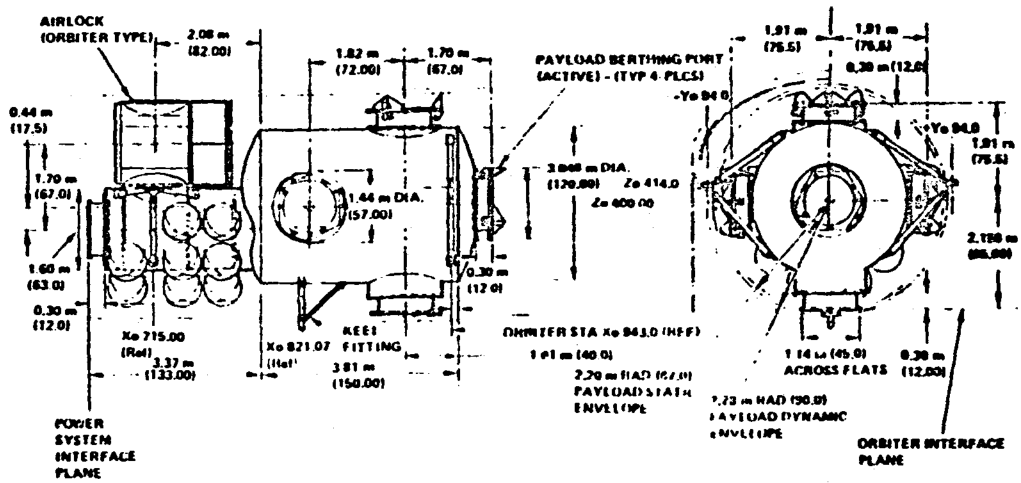
Figure 6.2-1

AIRLOCK/ADAPTER OUTBOARD PROFILE



relationships are based on the logic that this module is the key element of the MSP, critical elements of the ECLS, data processing, habitability and emergency systems have been allocated to this module.

The module is configured in three sections: (1) main cabin, (2) airlock, and (3) airlock tunnel. The 3.04M dia x 3.81M long main cabin is sized to provide four (4) radial, external-mounted, berthing ports with the physical limitations of the Orbiter cargo bay. The ± Y axis berthing ports are offset from the ± Z ports in accordance with interface parameters established by the Orbiter systems. The -Z port incorporates a passive interface mechanism configured to mate with the Orbiter berthing/docking system. The remaining radial ports and the +X port incorporate active berthing mechanisms. The internal arrangement shown in Figures 6.2-2, 6.2-3 and 6.2-4 incorporate three subsystem racks, portable water storage system, waste management compartment, and a maintenance workbench/ storage rack. The airlock is an Orbiter airlock equipped with all standard components necessary to support EVA. The airlock is mounted to a 1.60M dia tunnel section with internal racks sized to accommodate emergency provisions, backup food storage, and EVA support equipment. The tunnel also incorporates

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Figure 6.2-2

AIRLOCK/ADAPTER INBOARD PROFILE

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(PORT SIDE)

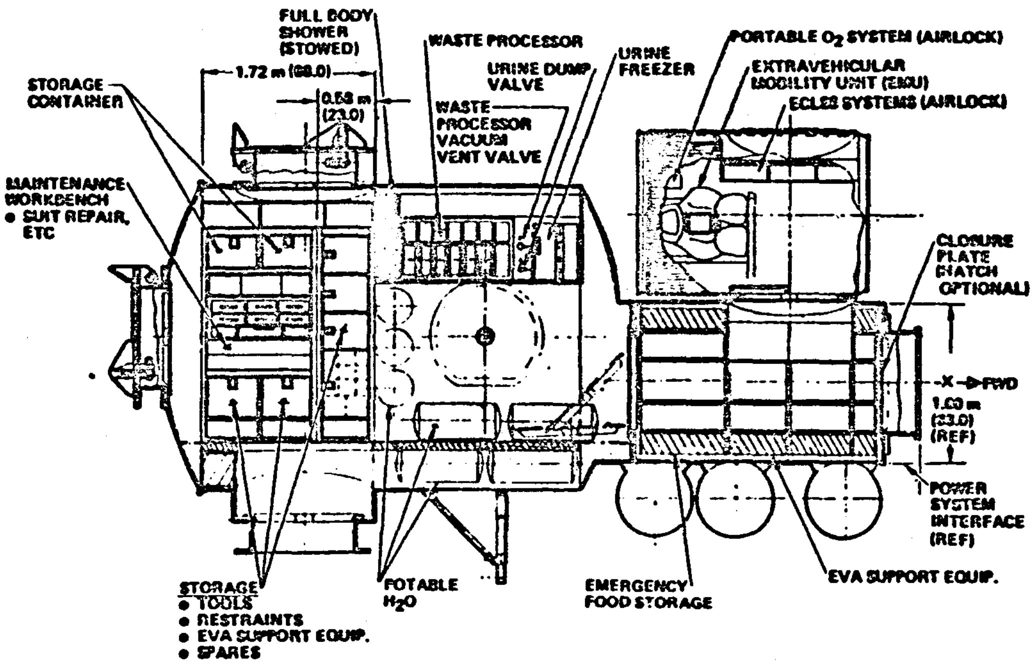

Figure 6.2-3

VFO498

AIRLOCK/ADAPTER INBOARD PROFILE

(STARBOARD SIDE)

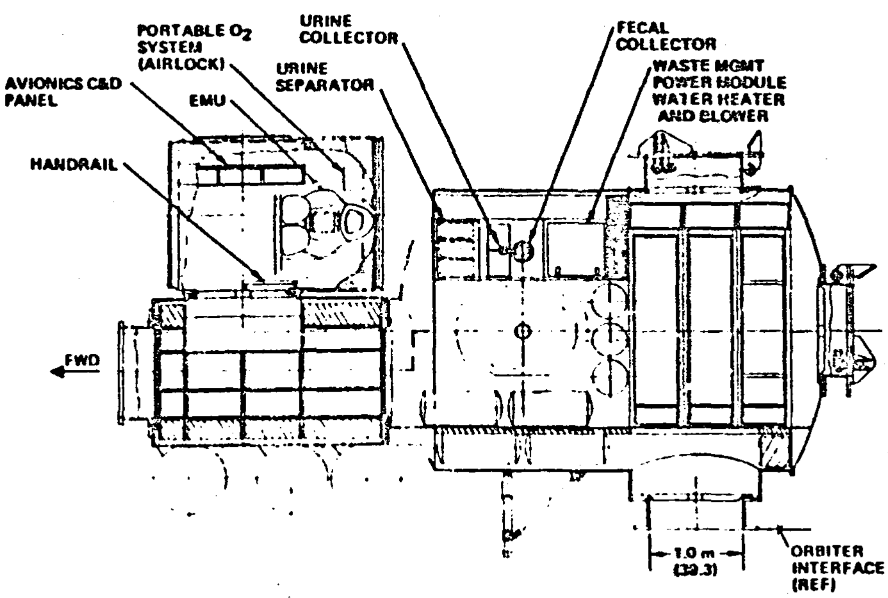

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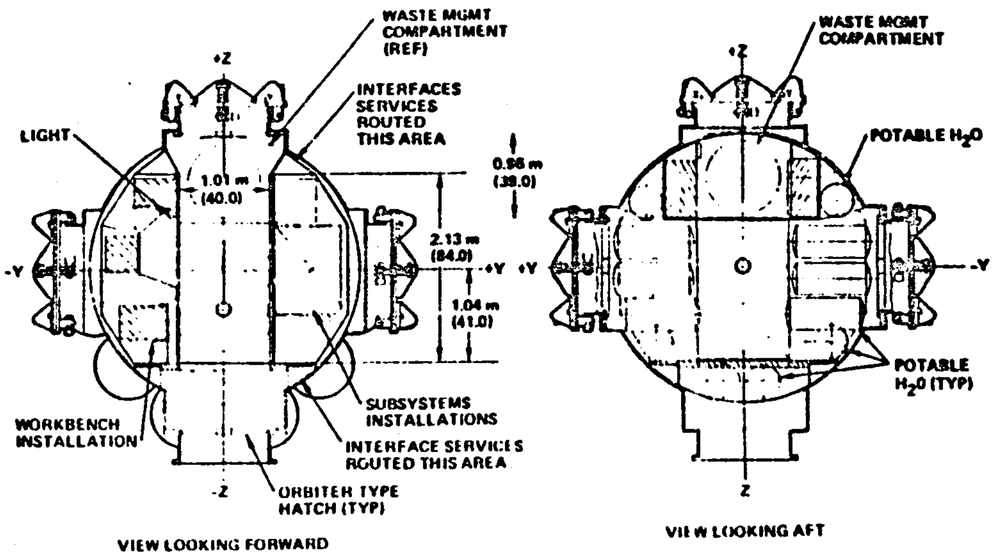
Figure 6.2-4

AIRLOCK/ADAPTER INBOARD PROFILE



a passive berthing mechanism for mating to the Power System. The MSP atmosphere storage tanks are mounted external to the airlock tunnel.

The airlock/adapter overall length of 8.12M is the maximum length module that can be launched with a two-segment habitability module. Location of the habitat in the cargo bay has a direct influence on the size and shape of the airlock/adapter.

6.3 HABITABILITY MODULE

The favored habitability module configuration is shown in Figures 6.3-1 and 6.3-2. One of the key study ground rules was to use available hardware and technology insofar as practical in order to develop a cost-effective total system. For this reason, the cylindrical pressure shell sections of the current European Spacelab were determined to represent feasible basic building blocks for the habitability module because these sections were designed specifically for use with the Orbiter.

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Figure 6.3-1

VFO486

HABITABILITY MODULE INBOARD PROFILE
(STARBOARD SIDE)

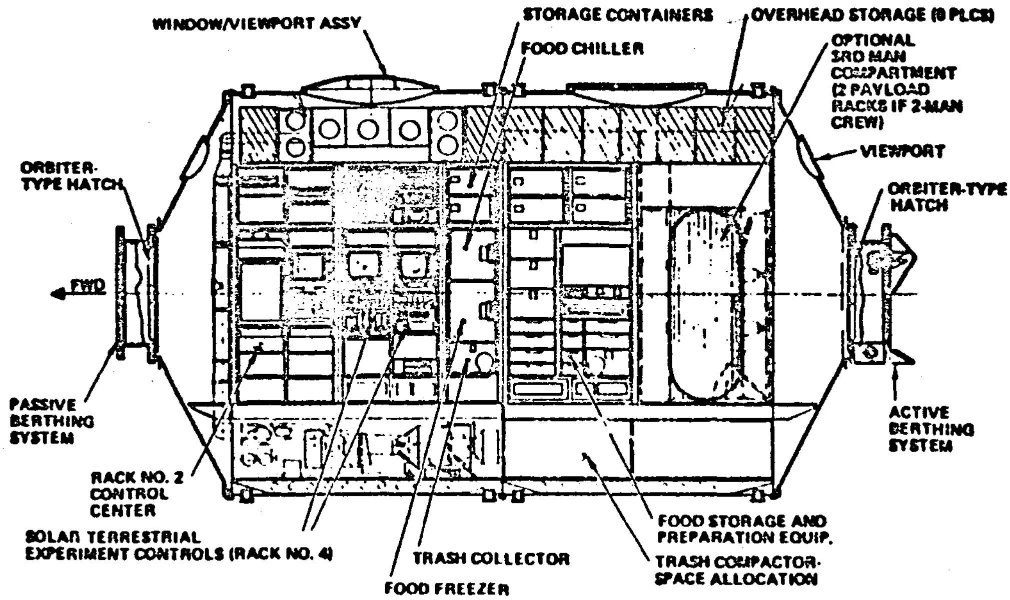
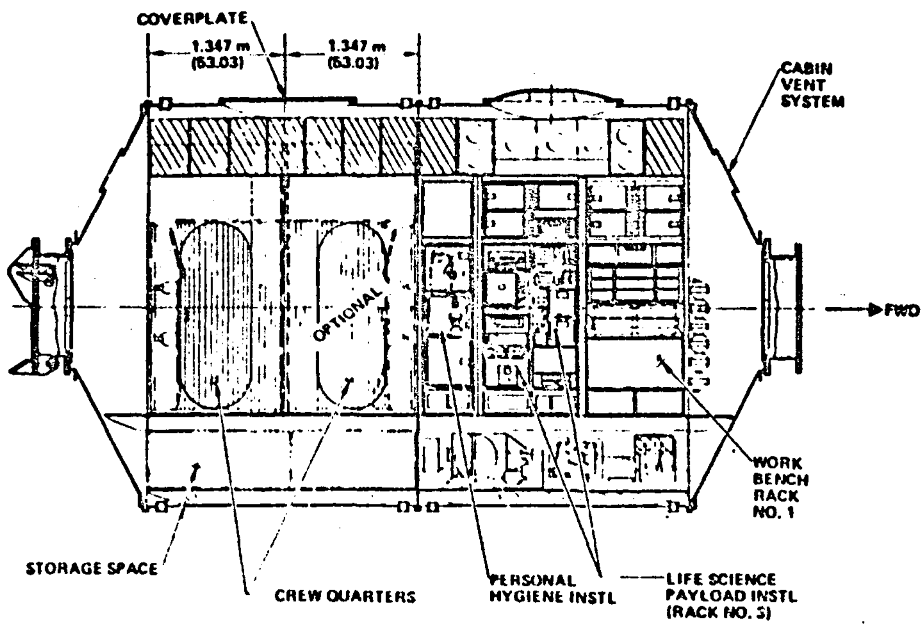


Figure 6.3-2

VFO484

HABITABILITY MODULE INBOARD PROFILE
(PORT SIDE)



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Previous studies have suggested that 200 cu.ft/man is an acceptable lower limit of free volume for habitable vehicles. Accordingly, at least 600 cu.ft. of free volume would be required in a three-man habitability module.

Predicated upon an equipment packing density of 60 percent and the requirement for 600 cu.ft. of free volume, the volume of the three-man habitability module should be at least 2000 cu.ft. Utilizing two cylindrical sections of the Spacelab, a volume of 2450 cu.ft. can be obtained. As a result, a two-segment Spacelab was selected as the size of the habitability module. Two segments, the core segment and the crew accommodation segment, together with the end cones comprise the habitability module. The exterior is covered with high-performance insulation. EVA mobility aids are also located on the exterior.

Subsystem equipment is primarily located forward in the core segment. It is installed in the first double rack on each side (Rack No. 1 and 2) and on the sub-floor extending the entire length of the core section. The remaining 60 percent of the core section accommodates two double racks (Rack 3 and 4) of mission-oriented equipment. Rack 3 accommodates the life science payload equipment and Rack 4 accommodates controls for the solar terrestrial experiments. The food chiller and freezer components of the food management system are installed in single Rack No. 6, and Rack 5 has the personal hygiene installation. The workbench (Rack No. 1) is primarily intended to support work activities that are general in nature and not associated with a unique experiment. The workbench has storage facilities, such as utility drawers, file cabinets and tissue dispensers. Also, lighting is installed in a recessed area above the work surface. Tools and maintenance equipment are provided in the workbench storage containers and will be used to supplement the equipment stowed in the airlock/adapter.

Three spacious well-equipped private crew compartments (145 cu.ft. each) are located in the aft crew accommodation section. Each compartment has a privacy closure to somewhat isolate the crew from external light and sound. Also, each compartment has internal lighting, controlled temperature, ventilation, sleep restraints, storage lockers, trash bags, communication, fold-away writing platforms and audio entertainment center.

The food management subsystem is also incorporated in the aft section and provides for the storage, preparation and consumption of food as well as collection of food waste and debris.

Trash bags for temporary storage are located throughout the MSP in areas where high trash generation is anticipated. The trash bags are collected and placed in the trash compactor located under the floor of the crew accommodation section. The compacted trash is off-loaded to the Orbiter and/or logistics module for return.

6.4 LOGISTICS MODULES/ROUTINE AND CONTINGENCY

The initial MSP will provide a limited 90-day supply of expendables and consummables for a crew of three, plus a 30-day contingency supply. As a result, the MSP will be supported through a logistics resupply system which will provide both replenishment of existing stores and additional on-orbit storage capability. The logistics module is relatively inactive inasmuch as its main function is storage and to support transfer of Platform supplies. It also serves to return data, specimens, and accumulated trash to Earth. The favored logistics module configuration is shown in Figure 6.4-1. It is 4.32M in diameter x 7.31M long and is configured to provide a pressurized, controlled environment for cargo requiring such an environment plus an unpressurized section for atmospheric resupply tankage. The vehicle is sized to supply 180 days of expendables to the MSP. The pressurized section is a one-segment Spacelab structure with a "birdcage"-type interior rack system. The racks are sized to accommodate 19.0-inch wide equipment and/or storage containers, making them interchangeable with various MSP internal racks. The unpressurized section is a 4.32M dia x 2.84M long structural element configured to house a total of 30 GO_2 and GN_2 tanks. A 1.14M diameter tunnel is incorporated through this section to provide IVA access through the module to an adjacent module or to permit rescue if required. The pressurized compartment incorporates the passive berthing system which interfaces with the airlock/adapter, thus keeping the high pressure tanks the maximum distance from the cluster as possible. The tunnel incorporates the active berthing system.

As described in an earlier section (Section 4.2, Logistics Modules), there is a need for some low-cost, quick reaction unmanned logistics module. Such a

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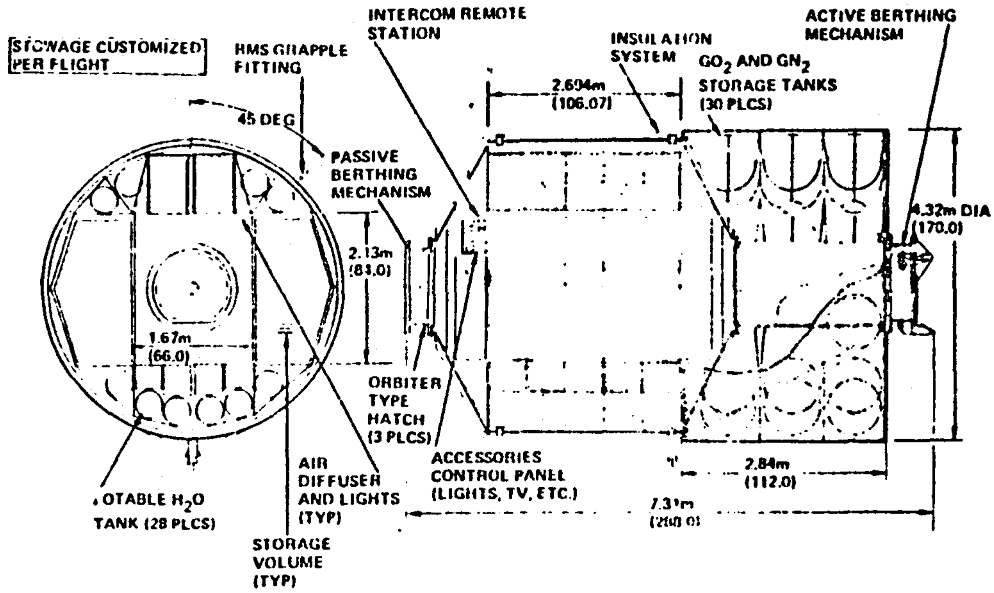
Figure 6.4-1

LOGISTICS MODULE — 180-DAY CONFIGURATION



capability would be employed in the event that the Shuttle cannot be launched for a revisit in a timely manner or if the logistics need is not great enough to warrant a dedicated or even shared flight. Figure 6.4-2 illustrates the design of such a system. This capability is not included in the system costs.

6.5 OPTIONAL EXTERNAL PAYLOAD SUPPORT BEAM (NOT IN WEIGHT OR COST ESTIMATES)

This beam is needed for technology experiments on large payload structural elements, OTV tankage, spacecraft servicing and possibly even for berthing the Teleoperator Maneuvering System. Figure 6.5-1 shows a long articulating payload support beam with multiple pallet berthing ports. A rotating joint is incorporated to allow + 180° rotation of the arm for pointing and ease of accessibility during loading and unloading. The folding joint facilitates on-orbit assembly by rotating clear of the Orbiter cargo bay. The folding rotation feature increases payload viewing capability. The structural element of the beam is a graphic/epoxy truss configuration, 1.4M x 1.4M square x 9.0M long. Two payload berthing stations are incorporated to accommodate palletized experiments and/or

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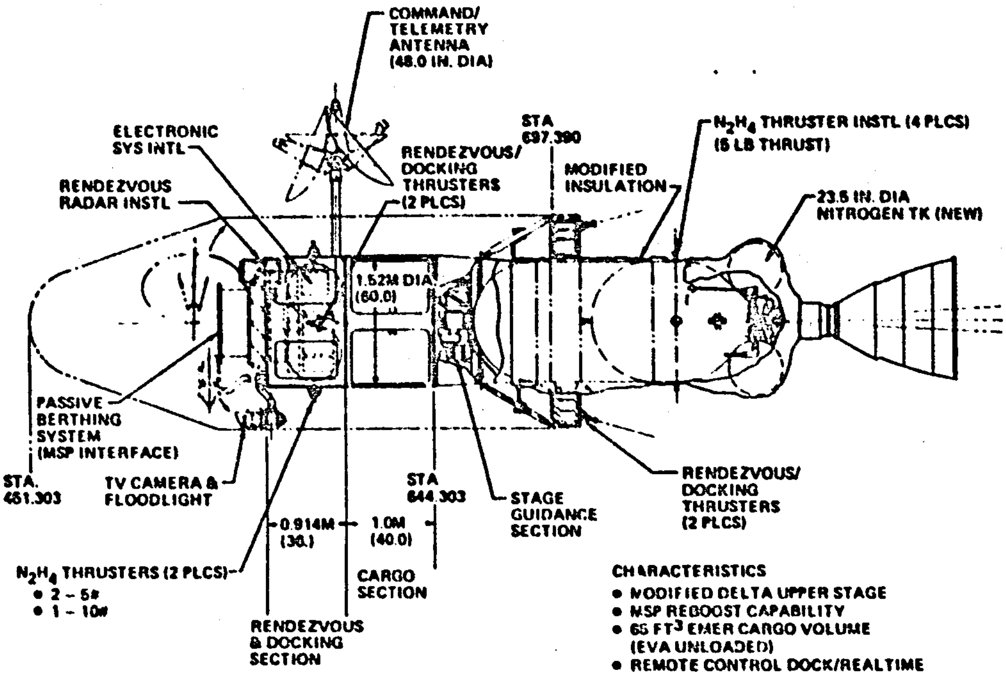
Figure 6.4-2

CONTINGENCY UNMANNED LOGISTICS SYSTEM



assembly elements. The inner port may be used as a parking port for module exchange operations. Note that this beam is an advanced use option which replaces the shorter, less capable "arm" (1 of 3) which is part of the basic Space Platform and is moved aft from its original position (on the Space Platform) to the end of the central module, where it serves as a rotating mount for Earth-viewing palletized payloads.

6.6 ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM (ECLSS)

Key features of the selected ECLSS, highlighted in Table 6.6-1, include use of the basic Spacelab ECLSS which has been improved with the addition of condensate water recovery and a regenerative CO_2 removal. These improvements reduce resupply and represent cost savings partly due to a reduced number of water tanks and LiOH expendables.

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Figure 6.5-1

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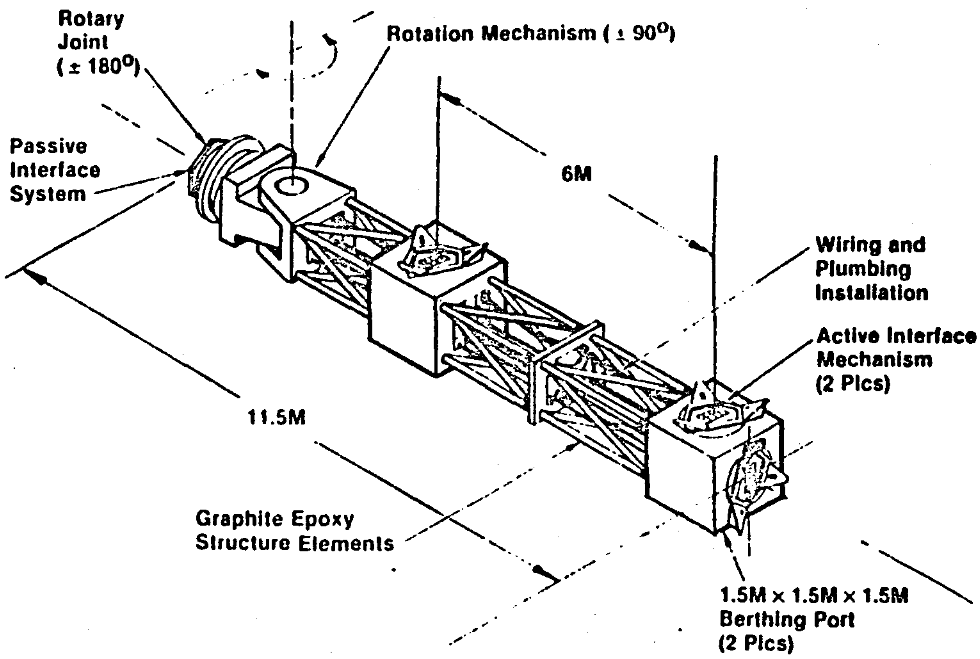
PAYLOAD SUPPORT BEAM
(LONG, ARTICULATING OPTION)



HAMILTON STANDARD

Table 6.6-1

KEY FEATURES OF MSP ECLS

- Regenerable CO_2 Removal
- Partial Water Loop Closing
- Fail-Operational/Fail-Safe
- Maintainable Equipment
- 100% Crew Overload Capability
- No Throwaway Growth Design
- Optimum Use of Existing Qualified Equipment
- Low Cost and Low Program Risk

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Built-in redundancy for critical functions results in fail operational capability for each of the two separate ECLSS subsystems. Since each ECLSS is sized to accommodate the full crew, a 100 percent overload capability exists for crew turnover operations. Maintenance capability enables replacement of failed or outdated components so that the subsystem can be restored to initial or changed to improved capability.

The design has a no-throwaway feature in that the solid Amine CO_2 removal system can be used in the growth version. Instead of the CO_2 being directed overboard, it will be directed to a Sabatier unit for O_2 recovery. The condensate recovery unit will be used for cleanup of water processed in a vapor compress./distill. or thermoelect. integr. membrane evap. subsystem.

Trade results indicated that an optimum design should include about 75 percent of Spacelab and Orbiter existing qualified hardware. This feature, along with no requirement for advanced technology, results in a low cost and low program risk design.

The ECLSS equipment is arranged to provide for two separate and independent units servicing the two separate compartments shown in Figure 6.6-1. The habitat module forms one compartment, the second compartment consists of the airlock/adapter, the logistics module and the payload module. No forced circulation exists between the two compartments and each is serviced by a separate cooling water loop.

Each major module contains a Spacelab ECLSS and a regenerative CO_2 removal unit. The Spacelab CO_2 control assembly is used for odor/contaminant control by replacing the LiOH canisters with charcoal canisters. Twelve LiOH canisters are retained in storage for emergency CO_2 control. Catalytic oxidizers are located in the life sciences module and the habitat module.

Condensate processing (multifiltration) assemblies are located in the habitat module and the airlock/adapter. Contingency water is stored in the airlock/adapter; normal resupply water resides in the logistics module.

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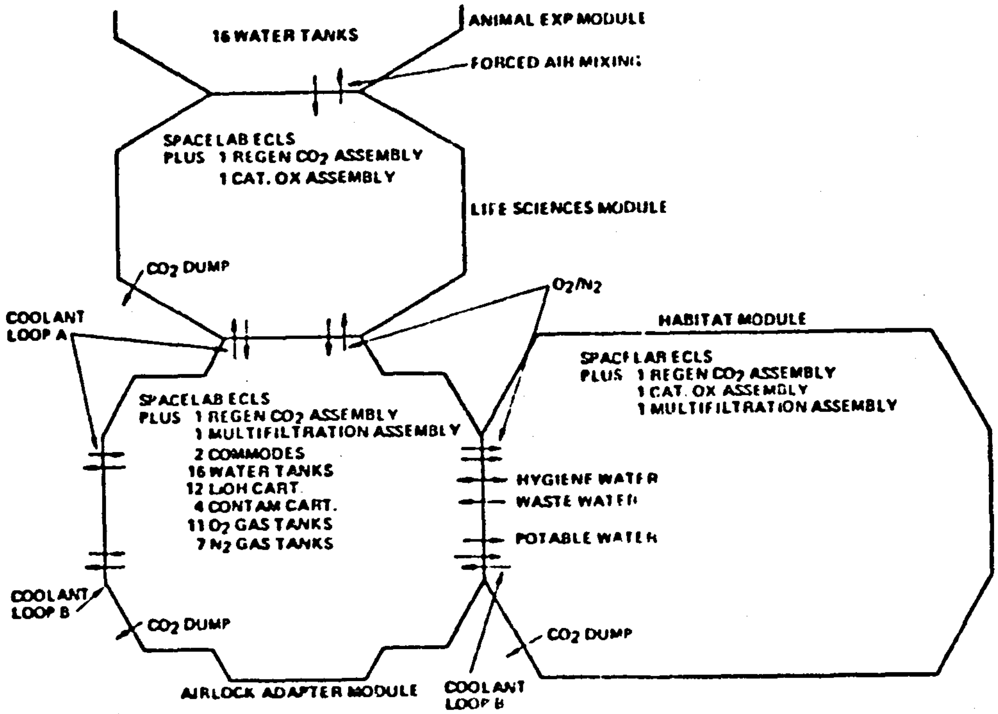
Figure 6.6-1

HAMILTON STANDARD **BASIC MSP ECLS EQUIPMENT LOCATION** VF0648



Contingency oxygen and nitrogen are stored on the exterior of the airlock/ adapter; normal resupply tanks are mounted on the exterior of the logistics module.

6.7 COMMAND AND DATA MANAGEMENT SUBSYSTEM (CDMS)

A CDMS concept has been developed for the Manned Platform that accommodates a wide range of missions and crew activities and can be implemented with low risk. The key features of the CDMS concept are shown in Table 6.7-1. The concept was based on existing equipment designs to show that such an approach is feasible. However, it is apparent that significant gains in performance, reliability and weight are available by using CDMS equipment that is based on current electronics technology. The selected concept uses hardware elements from the Orbiter and Spacelab CDMSs and enhances the subsystem reliability by using additional on-line redundancy plus onboard spares that can be installed

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Table 6.7-1

CDMS FEATURES

- **Utilizes Daveloped Equipment**
- **Provides Flexible Crew Accommodation**
- **Accommodates PS and Orbiter Interfaces**
- **Exhibits Improved Reliability**
- **Accommodates Platform Growth**

by crew members. Platform growth is accommodated in the CDMS through the use of multiple-access data buses for data acquisition and distribution and by the use of standard module-to-module interfaces for data exchange.

Figure 6.7-1 shows that part of the CDMS that acquires, stores, processes, displays and distributes subsystem and experiment data. Spacelab CDMS equipment is widely used. Modifications are required to the Input/Output (I/O) units to accommodate the Power System interface and to be compatible with the additional redundant units (e.g., computer and MMU). The data buses can be extended to additional modules as the platform evolves. These added modules could have Remote Acquisition Units (RAU) under control of the central computer complex or could have I/O units and processors to accommodate a more autonomous data processing approach.

In addition to these services, the CDMS provides capabilities for audio communications, both intra-vehicle and with the ground, Orbiter and other external elements, video acquisition, display and communication, timing signal generation

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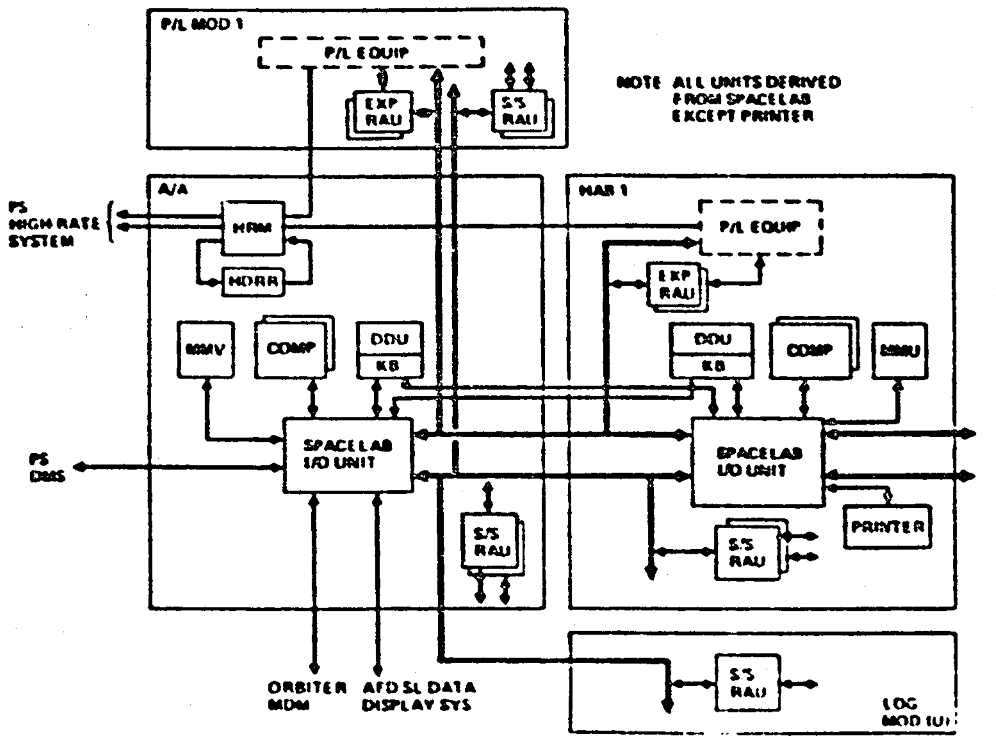
and distribution and caution and warning display. The hardware required to implement these functions is not a difficult development and can, for the most part, be derived from Shuttle and Spacelab.

Figure 6.7-1

PLATFORM
DATA MANAGEMENT SUBSYSTEM



The software key features and issues inherent in this DMS prospect are listed in Tables 6.7-2 and 6.7-3.

Table 6.7-2

MSP SOFTWARE — KEY FEATURES

- Standardized, Tightly Controlled Interfaces
  - Data Formats and Definition
  - Data Transfer Protocols
  - Display Formats
- Common Executive Designed to Support Transportable Applications Modules
- Single HOL
- Selected Use of Distributed, Embedded Processors
- Extensive Ground Validation Prior to On-Orbit Configuration Changes
- Build on Spacelab Software

Table 6.7-3

MSP SOFTWARE — KEY ISSUES

- Multiple Hardware Configurations
- On-Orbit System Integration
- Flight System Autonomy
- Development Cost and Schedule

6.8 POWER DISTRIBUTION SUBSYSTEM

This subsystem must interface with the Space Platform (Power System) and distribute regulated 30 VDC main bus power to subsystems and experiments in the SAMSP core modules and attached payloads. In addition, a three-bus 30 VDC interface is provided at the Orbiter berthing port. The basic EPS must retain flexibility to accommodate platform growth and to distribute power over increased line lengths to subsystem and experiment load centers.

The concept for this subsystem is sized to accept the 25 kW rated output of the Power System at the three-bus 30 VDC interface. The design makes maximum use of Spacelab equipment and subsystem design. Emergency power buses are derived from the main buses in the airlock/adapter power distributor. Design features are summarized in Table 6.8-1.

Table 6.8-1

SELECTED ELECTRICAL POWER DISTRIBUTION SUBSYSTEM DESIGN

- Spacelab Derived Design
- Nominal 25 kW Rating
- 30 VDC Main and Emergency Power Buses
- AC Power from Local Inverters
- Combination Manual/Automatic Power Management
- Single Point Ground
- Growth Provisions

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Trades and issues studied include (a) impact of subsystem power requirements, (b) configurations for supplying AC power, (c) EPS growth options, and (d) considerations of emergency power.

Subsystem power consumption based on using Spacelab equipment accounts for nearly one-half of the power from the 25 kW Power System and over 90 percent in the case of a 12.5 kW Power System. Average DC and AC power requirements for the Platform subsystems by module location are given in Table 6.8-2. Possible means for reducing subsystem power consumption are identified in the study.

The selected scheme for AC power distribution (distributed inverters) is based on the use of Spacelab inverters and AC load transfer provisions that are compatible with Spacelab AC power switching.

Table 6.8-2

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SUBSYSTEM AVERAGE POWER IN WATTS

	Logistics Module		Airlock/ Adapter		Habitability Module		Payload(1) Modules	
Subsystem	DC(2)	AC(3)	DC	AC	DC	AC	DC	AC
CDMS	19	—	1274	154	1232	154	179	—
ECLS	45	—	362	1502	416	1601	335	592
HAB	120	—	2	10	153	6	—	—
EPDS(4)	44	—	651	—	719	88	429	30
Subtotals	228	—	2326	1749	2483	1849	943	622
Total DC and AC	228		4075		4332		1565	

(1) Initial Version — Total for Two Life Science Payload Modules
(2) 28 Vdc
(3) 115/200 Vac 400 Hz
(4) Includes Allowances for Subsystem Wiring and Inverter Losses

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Power distribution options for accommodating Platform growth include extension of the main 30 VDC power buses and utilization of the Power System 120 VDC interface. Voltage drops through the system can result in unacceptable low voltages at the experiments for an extended 30 VDC system. Utilizing the 120 VDC interface introduces a double penalty for regulation; i.e., 120 VDC regulators in the Power System and 30 VDC regulators on the Platform. The preferred alternative is to take power directly from the Power System unregulated high voltage buses.

Provisions for emergency power beyond the emergency buses in the baseline design depend on requirements for contingency operation. Backup batteries could be added to assure continuous operation of critical control functions. In the extreme, additional batteries could be required as part of a crew survival/rescue kit.

6.9 STRUCTURAL/MECHANICAL SUBSYSTEM

An overall assessment of the MSP structure was made to surface concerns that must be addressed in the future. Concerns for each of the MSP modules and the assembled Platform are listed in Table 6.9-1. From a systems standpoint, docking joint compliances and thermal distortion effects on pointing are the most significant items.

Docking joint compliances require an in-depth analysis to ascertain dynamic response/MSP attitude control interaction. Attention must be paid to design details that affect joint compliance and an iterative design/analysis process may be required to solve the compliance problem.

Thermal distortion is a pointing problem because orbit position and structural temperatures are related and are transient parameters. Estimates of stable temperatures, temperature gradients and repetitive temperature changes are necessary to adequately predict structural deformation and the capability for fine pointing. Experiment location on the Platform is also a factor in pointing when more than one experiment is pointing at the same time. A design limit needs to be established for Platform controlled pointing. A systems study of experiment pointing requirements is needed to define the limit. Any requirements exceeding the limit will necessitate auxiliary pointing equipment on the experiment.

Table 6.9-1

STRUCTURAL/MECHANICAL CONCERNS

VF073b

Spacelab Module

- End Dome Strength For Docking Loads
- 10-Yr Life Limitations

Airlock/Adapter Module

- High Pressure System Design Assurance
  - Design Factors of Safety
  - Fracture Mechanics Analysis
  - Meteoroid Penetration Protection
- Airlock Fatigue Life

Assembled Platform

- Docking Joint Compliances Increase Assembly Flexibility (Dynamics/Control Problem)
- Thermal Distortions Affecting Pointing Requirements
- Design For "Leak-Before-Failure" Condition to Preclude Catastrophic Pressure Loss
- Reboost Loads on Modules and Connections

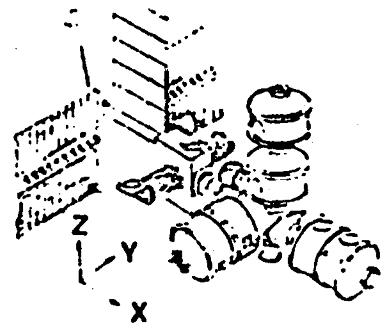
6.10 ATTITUDE CONTROL ASPECTS

An orbital disturbance moment analysis was performed to assess whether the Reference Space Platform (SP) CMG and magnetic torquer sizing was adequate for a typical Manned Space Platform (MSP) configuration. The results are preliminary because the MSP flight requirements and the momentum management operational scheme are not well defined. The results were generated based on assumptions and conditions which are shown on Figure 6.10-1.

The moment disturbances on the MSP which were analyzed were aerodynamic, gravity gradient and gryoscope (local vertical orientations). Past analyses have shown that aerodynamic moment can be significant at the orbital altitudes planned for MSP (370-435 km). Three atmospheric density conditions were assumed; representing medium, high and worst-case conditions. The density histories were generated with the Jacchia III atmosphere model (NASA SP-8021, March 1973).

Figure 6.10-1

REFERENCE SP ACS SIZING ANALYSIS



Reference Space Platform (25 kW)

- **Three Modified Skylab CMGs**
- **Four Space Telescope Magnetic Torquers**

Conditions Analyzed

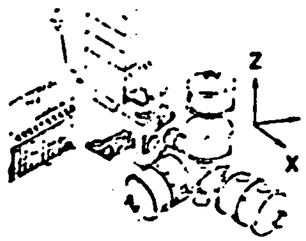
- **200 and 235 nmi Altitudes**
- **0, 40, and 80 deg β-Angles**
- **57.5-deg Inclination**
- **Medium, High, and Worst-Case Atmosphere Densities**
- **June 21 — Time of Year**
- **Five Inertial Orientations**
- **Two Local Vertical Orientations**

The MSP configuration chosen in the analysis is shown on Figure 6.10-2. The solar array size corresponds to a 25 kW electrical power capability to the payloads. The Space Platform payload modules include an habitability/payload module (opposite end from solar arrays), an airlock/adapter (connects modules to Reference SP), a logistics module (left side), a life science research laboratory (second from top).

Typical results of the MSP external disturbance analysis are shown in Figure 6.10-2. The results are in terms of how long an orientation can be maintained without saturating the CMG momentum capability and do not reflect orientation restrictions due to other considerations such as heat rejection or electrical power. In all cases, a 25 percent CMG momentum margin was maintained.

The Reference Space Platform ACS design of three Skylab CMGs and four Space Telescope electromagnets will allow operations of the MSP configuration studied. Operations may be restricted at times with respect to orientation hold duration for some orientations, especially at lower altitudes and higher atmospheric densities. The XPOP-YPSL orientation is relatively easy to control and is desirable for a number of reasons including good electrical power, heat

Figure 6.10-2



REFERENCE 25 KW PS ACS ORIENTATION HOLD CAPABILITY FOR MSP

Medium Atmospheric Density

Principal Axes Orientation	Orientation Hold Duration (Orbits)					
	235 nmi			200 nmi		
β (deg)	0	40	80	0	40	80
XPOP-YPSL	x	x	x	x	x	x
XPOP-ZPSL	x	x	x	x	x	x
YPOP-ZPSL	120	x	x	4	550	x
ZPOP-YPSL	44	x	x	3	x	x
ZSI-XIOP	x	3	26	8	2	13
ZLV-XPOP (YVV)	12	16	15	2	2	2
ZLV-YPOP (XVV)	x	x	x	x	x	x

Three Skylab CMGs and Four Space Telescope Electromagnets

rejection and payload viewing capabilities. The XLV-YPOP(XVV) local vertical orientation is also relatively easy to control, but electrical power capabilities degrade approximately as the cosine of orbit Beta angle and may only be useful for low Beta angle orbits. The other local vertical orientation (ZLV-XPOP) has good electrical power and heat rejection at high Beta angles but may have limited hold duration because of the large thermal radiator-induced aero torques.

It should be noted that at 235 nmi altitude, all orientations studied can be held for at least one orbit and usually much more. Additional momentum control capability may be desirable, however, if a good orientation selection is required at lower altitudes. Also, additional momentum control capability may be desirable to maximize operational capability in the event a CMG or electromagnet fails.

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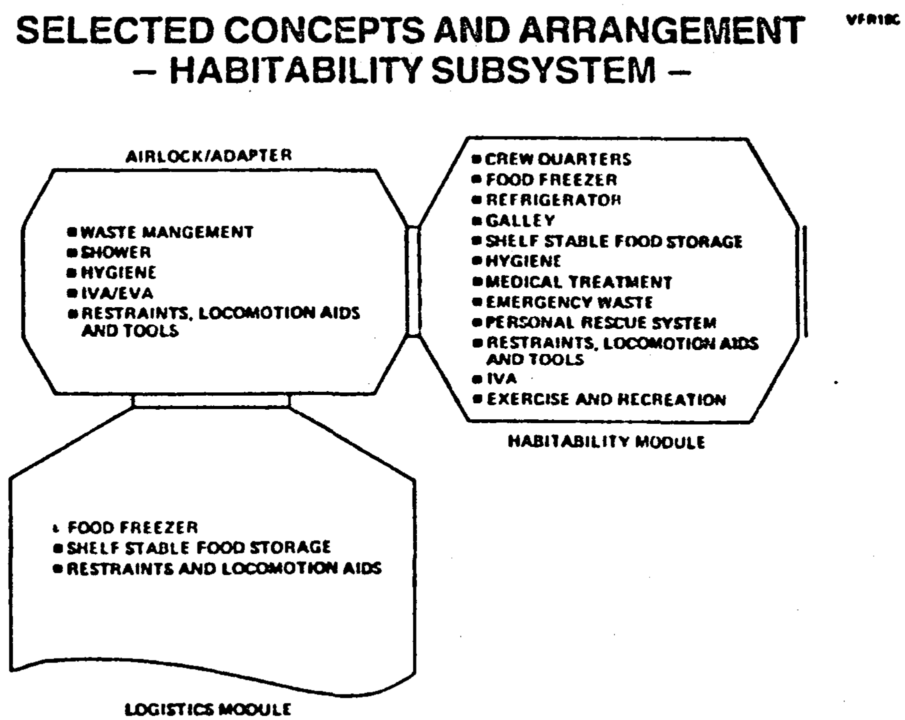
6.11 HABITABILITY SUBSYSTEM

This subsystem is designed to satisfy the two separate compartment requirements as shown in Figure 6.11-1. All essential functions are provided in the habitation module and duplicated in the airlock/adapter or logistics module. These essential features include food and water supplies and emergency waste management. Emergency escape capability consists of IVA, EVA, and personal rescue systems.

Figure 6.11-1

SELECTED CONCEPTS AND ARRANGEMENT – HABITABILITY SUBSYSTEM –



Primary habitation functions are provided in the habitation module where the crew quarters are located. These features include a galley, food storage, hygiene, medical treatment, and exercise and recreation provisions.

The primary waste management facility is located in the airlock/adapter and consists of the Orbiter waste management unit. Since the existing Orbiter design would necessitate changeout on-orbit, consideration is being given to

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locating the units in the logistics module so changeout can be done on the ground. Another alternate is to modify the Orbiter design to facilitate changeout.

The food diet consists primarily of frozen and shelf staple foods which are supplemented with fresh food during Shuttle revisits. The food resupply weighs 1400 pounds per 180 days for the basic MSP. The bulk of the food is stored in the logistics module, but 7 to 14 days supply is maintained in the habitation module for emergency use.

Eight of the 12 major habitability items are existing Shuttle and Spacelab designs, some of the items require improvements. Items requiring new designs include the trash compactor and freezer/refrigerator.

6.12 SAFETY

Because the crew of MSP has no immediate escape capability similar to Skylab, the MSP design incorporates several features dedicated solely to crew support and safety including emergency provisions and hazard retreat areas. These are highlighted in Figure 6.12-1. Contingencies are provided for in the MSP basic configuration and remedial safety aspects as onboard warning systems, 180-hour emergency supplies, 30-day contingency supplies, escape routes, and Orbiter rescue.

The approach to achieving an acceptable level of safety for the MSP has featured retreat-refuge (and recovery) rather than abandonment. Hazards have been minimized throughout design, operations and conceptual configuration effort, with special attention to location of potentially hazardous material. Backup provisions will permit operation of the MSP from either the habitat/payload module or the airlock/adapter module with full recovery possibilities if retreat from either module is required. Every pressurized module berthed to the MSP is a safe refuge area for a minimum of 180 hours. If recovery from a contingency is not possible, Orbiter rescue is always available as the final backup.

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Figure 6.12-1

KEY SAFETY FEATURES OF BASIC CONFIGURATION

- 2 Separate Pressurized Habitable Volumes
- Separate Subsystems for Each Volume
- Repressurization Stores For Largest Pressurized Volume
- 3 Isolated Power Source Buses
- Emergency Power Distribution Provided
- Overpressure Protection and Emergency Atmosphere Dump Capability in Each Pressure Volume
- Critical Subsystem Functions Are Fail-Operational/Fail-Safe
- EVA Rescue Routes Provided in Each Separate Habitable Volume

6.13 MASS PROPERTIES

The weight of the Manned Platform elements are given in Figure 6.13-1, with groupings for each of the three launches required to emplace the system.

6.14 KSC OPERATIONS

Prelaunch sustained logistics operations at this center will require a considerable planning and process management activity. Prospects for logistics are listed in Figure 6.14-1.

6.15 GROWTH MODES

This configuration and module approach lends itself effectively to growth modes for the support of all of the various payloads (near-term and future) identified earlier in this report (see Figure 6.15-1).

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Figure 6.13-1

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MANNED PLATFORM LAUNCH WEIGHT SUMMARY

Elements	First Launch	Second Launch	Third Launch	Orbital Assembly
Manned Platform Modules		32.244	20.333	55.005
Airlock Adapter	—	16.112	—	16.112
Habitability	—	16.132	—	16.132
Logistic	—	—	20.333	20.333
Payloads	7.231		14,741	21,972
Solar Terrestrial (Pallet)	7.231		—	7.231
Earth Science (Pallet)	—		5.141	5.141
Life Science Specimen Facility	—		9.600	9.600
Power System	29.887			29.887
25.0 Kw Power System with Reboost Module	27.459			27.459
Mini-Arms (3)	2.428			2.428
Orbiter Support	6.748	6.410	6.571	510
Crew (3)	—	510	—	510
Docking Module	3.900	3.900	3.900	—
Orbiter Payload Restraints	2.768	1,920	2.591	—
Orbiter Payload Flight Kits	80	80	80	—
Total (Lb)	43.856	38.654	41.645	107,374

Note: Contingency Incorporated in Individual Elements

Figure 6.14-1

KSC ROLE IN LOGISTICS

VFR272

- Manned Platform Logistics Management
  - Requirements Analysis
  - Planning and Scheduling
  - Facility Utilization
  - Training
  - Operations Control
- Logistics Integration Operations
  - Manned Module Support
  - Space Platform Support
  - Interior Payload Modules
  - Exterior Payload Modules
  - Large Structure Build Up
  - OTV Basing/Resupply
  - Spacecraft Servicing
  - Subsatellite Servicing
- 180 Day Logistics Module Turnaround (Typical)
  - Unload
  - Refurbish
  - Load Internal/Externally Stored Consummables for Manned Modules and Space Platform
  - Load Payload Resupplies
  - Load New Payloads
  - Load On-Orbit Operations Aids
- Training for On-Orbit Logistics and Related Operations

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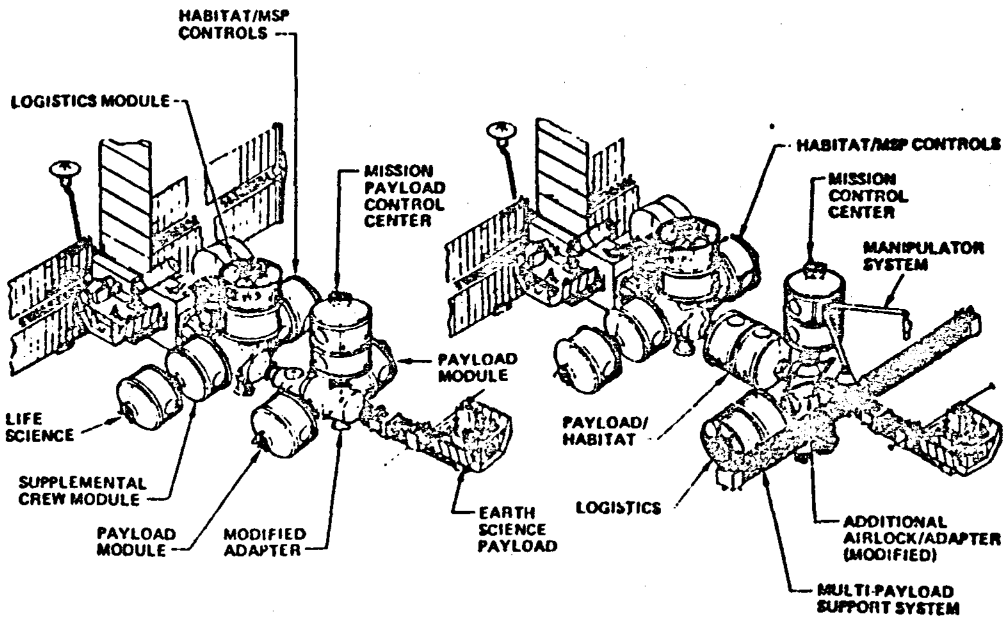
Figure 6.15-1

VFR130

MANNED PLATFORM GROWTH OPTIONS



6.16 DETAILED EQUIPMENT AND MASS PROPERTIES LISTS

Figures 6.16-1 through 6.16-9 present details on these subjects, including a summary presentation of subsystem weights for each module.

6.17 INBOARD PROFILE DRAWINGS

Layout drawings of the recommended central module, habitability module and logistics module are bound into the back of this document.

6.18 MINIMUM COST/EARLIEST CAPABILITY CONCEPT

(Presented after Figure 6.16-9.)

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Figure 6.16-1

BASIC MANNED PLATFORM EQUIPMENT

VFR283

(ENVIRONMENTAL CONTROL & LIFE SYSTEM)

ASSEMBLY	NO. AND LOCATION A/A	HAB	LOG.
*ECLS			
ATM STORAGE & CONTROL			
• N_2 TANKS	6	–	12
• N_2 FILL AND RELIEF	✓	–	✓
• O_2 TANKS	12	–	18
• O_2 FILL AND RELIEF	✓	–	✓
• O_2/N_2 CONTROL PANEL	1	1	–
• VENT AND RELIEF VALVES	1	1	1
• SENSOR PANEL	1	1	–
• LINES AND DISCONNECTS	✓	✓	✓
• AIRLOCK PRESSURE CONTROL	1	–	–
• GN_2	✓	–	✓
• GO_2	✓	–	✓
ATMOSPHERE REVITALIZATION			
• CO_2 CONTROL	1	1	–
• AIR TEMPERATURE CONTROL	1	1	–
• CONDENSATE SEPARATOR	1	1	–
• CONDENSATE PROCESSOR	1	1	–
• COND STORAGE & DUMP	1	1	–
• CONTAMINANT CONTROL	–	1	–
• INTERCHANGE CURCULATION	1	–	–
• ODOR CONTROL & CHARCOAL	1	1	–
• CATALYTIC OXIDIZER	–	1	–
• AVIONICS FAN ASSEMBLY	1	1	–
• AVIONICS HX	1	1	–
• RACK COOLING HARDWARE	4	7	–
• FIRE DETECTION & SUPPRESION	1	1	1
• DUCTING	✓	✓	✓

ASSEMBLY	NO. AND LOCATION A/A	HAB	LOG.
*ECLS (CONT)			
WATER MANAGEMENT			
• WATER TANKS	16	–	28
• WATER DISTRIBUTION	✓	✓	✓
• WATER HEATER/ CHILLER	1	–	–
• WATER MONITORING	1	–	–
• WASTE WATER DUMP ASSY	2	–	–
• WATER	✓	–	✓

Figure 6.16-2

MANNED PLATFORM EQUIPMENT

(COMMUNICATION, DATA MANAGEMENT & ELECTRICAL POWER SYSTEMS)

VFR282

ASSEMBLY	NO. AND LOCATION A/A	HAB	LOG.
*COMM & DATA MANAGEMENT SYS			
DATA MANAGEMENT			
• INPUT/OUTPUT UNIT	1	1	–
• COMPUTER	2	2	–
• DDU/KEYBOARD	1	1	1
• MASS MEMORY UNIT	1	1	–
• PRINTER			
• SUBSYSTEM RAY	2	2	1
• EXPERIMENT RAY	–	2	–
• D&C – MSP SYSTEM			
• D&C PAYLOAD SYSTEM			
• HRM	1	–	–
• HDRR	1	–	–
• WIRING	✓	✓	✓
TV			
• VIDEO SWITCHING UNIT	1	–	–
• VIDEO PROCESSOR	1	–	–
• VIDEO STORAGE UNIT	1	–	–
• VIDEO MONITOR	1	–	–
• TV CAMERA	1	2	–
• CAMERA CONTROL PANEL	–	1	–
• WIRING	✓	✓	–
TIMING DISTRIBUTION			
• TIMING DIST UNIT	–	1	–
• TIMING DISPLAY UNIT	1	1	–
• WIRING	✓	✓	–

ASSEMBLY	NO. AND LOCATION A/A	HAB	LOG.
*COMM & DATA MANAGEMENT (CONT)			
C&W/SAFING	1	–	–
• C&W DIST UNIT	1	–	–
• C&W ANNUNCIATOR PANEL	1	1	–
• C&W PROCESSOR	–	1	–
• WIRING	✓	✓	–
VOICE COMMUNICATION			
• INTERCOM REMOTE STA	2	3	1
• LOUD SPEAKERS	1	2	1
• EVA COMM SET	1	–	–
• AUDIO SEGNAL PROCESSOR	1	–	–
• AUDIO TAPE RECORDER	1	–	–
• INTERCOM MASTER STA	–	1	–
• WIRING	✓	✓	✓
*ELECTRICAL POWER SYS			
POWER DIST/CONVERSION			
• 30 VDC DIST	1	1	–
• EMER PWR DIST	1	1	–
• INVERTER	2	1	–
• SUBSYSTEM PWR DIST BOX	1	1	–
• EXP PWR DIST BOX	–	2	–
• WIRING	✓	✓	✓
POWER CONTROL			
• PWR CONTROL BOX	–	–	–
• EXP PWR SWITCHING PANEL	–	7	–
• MONITOR & CONT PANEL	1	–	–
• WIRING	✓	✓	✓

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Figure 6.16-3

BASIC MANNED PLATFORM EQUIPMENT

VFR265

(HABITABILITY SYSTEM)

ASSEMBLY	NO. AND LOCATION		
	A/A	HAB	LOG.
*HABITABILITY SYSTEM			
FOOD MANAGEMENT			
• FREEZER	-	1	-
• REFRIGERATOR	-	1	-
• GALLEY	-	1	-
• FOOD	-	✓	✓
• FOOD STOWAGE		✓	✓
• UTENSILS		✓	✓
TRASH MANAGEMENT			
• COMPACTOR	-	1	-
• CANNISTER & LINERS		✓	✓
RESTRAINTS & HANDRAILS			
• FOOT	✓	✓	✓
• HAND	✓	✓	✓
• STRAPS	✓	✓	✓
HYGIENE FACILITIES			
• CHAMBER SINK & DRYER	2	-	-
• SHOWER	1	-	-
• COMMODE ASSY	1	-	-
• EXPENDABLES	✓	-	-
HOUSEKEEPING			
• VACUUM CLEANER	1	1	1
• WIPES/TOWELS	✓	✓	✓

ASSEMBLY	NO. AND LOCATION		
	A/A	HAB	LOG.
FURNISHING			
• PARATITIONS	✓	✓	-
• DOORS	1	3	-
• TABLES	-	3	-
• DESK	-	1	-
• BUNKS	-	3	-
• NOISE ATTEN MATERIAL	✓	✓	✓
• LIGHTS	13	13	2
• STOWAGE CONTAINERS	✓	✓	✓
• WORKBENCH	-	✓	-
CREW EQUIPMENT			
• GARMENTS, ETC	-	✓	✓
• PERSONAL RESCUE SPHERE	-	3	-
• EVA SUIT		3	-
• CREW ACCESSORIES			
- TOOL KIT	✓	✓	-
FIRE EXTINGUISHERS	✓	✓	✓
• EMU	3	-	-
• PERSONAL HYGIENE			
• MEDICAL KIT	-	1	-
• IVA MASK	3	3	-
• EXERCISE & REC KIT	-	1	-

Figure 6.16-4

BASIC MANNED PLATFORM EQUIPMENT

VFR264

(STRUCTURE, MECHANICAL, AND THERMAL CONTROL SYSTEM)

ASSEMBLY	NO. AND LOCATION		
	A/A	HAB	LOG.
*STRUCTURE SYSTEM			
PRIMARY SHELL			
DOMES	2	2	2
CYLINDER SECTION	1	2	1
LONGITUAL STRUT ASSY	1	2	2
KEEL ASSY	1	1	1
FLOORING	✓	✓	✓
TUNNEL SHELL			
DOMES	1	-	1
CYLINDER SECTION	1	-	1
LONGITUAL STRUT ASSY	1	-	
AIRLOCK	1	-	-
SECONDARY STRUCTURE			
RACKS	✓	✓	✓
GRAPPLE FITTING	1	1	1
TANK SUPPORTS	✓	✓	✓

ASSEMBLY	NO. AND LOCATION		
	A/A	HAB	LOG.
*MECHANICAL SYSTEM			
HATCHES			
o INNER	1	-	1
o OUTER	5	2	2
BERTHING MECH			
o PASSIVE	2	1	1
o ACTIVE	4	1	1
o UMBILICALS	2	2	1
*THERMAL CONTROL SYSTEM ACTIVE THERMAL CONTROL			
o WATER PUMP PACKAGE	1	1	-
o COLD PLATES	6	9	-
o LINES & DISCONNECTS	✓	✓	-
o MISC	✓	✓	✓
PASSIVE THERMAL CONTROL			
o MLI BLANKETS	✓	✓	✓
o SUPPORT ETC	✓	✓	✓

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Figure 6.16-5

BASIC MANNED PLATFORM WEIGHT

VFR267

(ENVIRONMENTAL CONTROL & LIFE SYSTEM)

ASSEMBLY	WEIGHT (LBS) A/S	HAB	LOG
*ECLS			
ATM STORAGE & CONTROL	[2342]	[126]	[3860]
• N_2 TANKS	336	-	672
• N_2 FILL AND RELIEF	3	-	3
• O_2 TANKS	672	-	1008
• O_2 FILL AND RELIEF	3		3
• O_2-N_2 CONTROL PANEL	58	58	-
• VENT AND RELIEF VALVES	11	11	11
• SENSOR PANEL	10	10	-
• LINES AND DISCONNECTS	46	46	41
• AIRLOCK PRESSURE CONTROL	20		
• GN_2	340		825
• GO_2	744		1377
ATMOSPHERE REVITALIZATION	[878]	[1142]	[230]
• CO_2 CONTROL	38	38	
• AIR TEMPERATURE CONTROL	66	66	
• CONDENSATE SEPARATOR	22	22	-
• CONDENSATE PROCESSOR	105	105	
• COND STORAGE & DUMP	75	75	-
• CONTAMINANT CONTROL		32	-
• INTERCHANGE CIRCULATION	20		-
• ODOR CONTROL & CHARCOAL	110	40	-
• CATALYTIC OXIDIZER		32	-
• AVIONICS FAN ASSEMBLY	35	35	
• AVIONICS HX	34	34	-
• RACK COOLING HARDWARE	82	217	
• FIRE DETECTION & SUPPRESSION	158	108	131
• DUCTING	233	388	80

ASSEMBLY	WEIGHT (LBS) A/A	HAB	LOG
*ECLS (CONT)			
WATER MANAGEMENT	[2905]	[20]	[4856]
• WATER TANKS	640	-	1120
• WATER DISTRIBUTION	20	20	20
• WATER HEATER/ CHILLER	38	-	-
• WATER MONITORING	20	-	-
• WASTE WATER DUMP ASSY	64	-	-
• WATER	2123	-	3716

Figure 6.16-6

BASIC MANNED PLATFORM WEIGHT

(COMMUNICATION, DATA MANAGEMENT & ELECTRICAL POWER SYSTEMS)

VFR270

ASSEMBLY	WEIGHT (LBS) A/A	HAB	LOG
*COMM & DATA MANAGEMENT SYS			
DATA MANAGEMENT	[616]	[416]	[6]
• INPUT OUTPUT UNIT	68	68	
• COMPUTER	136	136	
• DISPLAY KEYBOARD	80	80	
• MASS MEMORY UNIT	25	25	
• PRINTER		40	-
• SUBSYSTEM BAY	34	34	6
• EXPERIMENT BAY		32	-
• HRM	64		-
• HDRR	108		
TV	[260]	[84]	[ ]
• VIDEO SWITCHING UNIT	48		
• VIDEO PROCESSOR	54		
• VIDEO STORAGE UNIT	108		
• VIDEO MONITOR	24	24	
• TV CAMERA	26	50	
• CAMERA CONTROL PANEL		10	
TIMING DISTRIBUTION	[6]	[34]	[ ]
• TIMING DIST UNIT		29	
• TIMING DISPLAY UNIT	5	5	

ASSEMBLY	WEIGHT (LBS) A/A	HAB	LOG
*COMM & DATA MANAGEMENT SYS (CONT)			
C&W SAFING	[36]	[34]	[ ]
• C&W DIST UNIT	21	-	-
• C&W ANNUNCIATOR PANEL	15	15	-
• C&W PROCESSOR		19	
VOICE COMMUNICATION	[68]	[32]	[4]
• INTERCOM REMOTE	4	6	2
STA	7	4	2
• LOUDSPEAKERS	2	-	-
• EVA COMM SET	30	-	-
• AUDIO SIGNAL PROCESSOR	20	-	-
• AUDIO TAPE RECORDER	8	-	-
• INTERCOM MASTER STA	-	22	-
*ELECTRICAL POWER SYS	[238]	[210]	[30]
POWER DIST CONVERSION			
• 30 VDC DIST	58	58	-
• EMER PWR DIST	5	5	5
• INVERTER	150	75	-
• SUBSYSTEM PWR DIST BOX	25	25	25
• EXP PWR DIST BOX		56	-
POWER CONTROL	[8]	[77]	[ ]
• PWR CONTROL BOX			-
• EXP PWR SWITCHING PANEL		77	
• MONITOR & CONT PNL	8		
WIRING	[502]	[1103]	[390]
• POWER	200	399	208
• SIGNAL	297	694	176
• BONDING STRAPS	5	10	5

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Figure 6.16-7

BASIC MANNED PLATFORM EQUIPMENT

VFR200

(HABITABILITY SYSTEM)

ASSEMBLY	WEIGHT (LBS) A/A	HAB	LOG
*HABITABILITY SYSTEM			
FOOD MANAGEMENT	[ ]	[1244]	[1811]
• FREEZER		-	90
• REFRIGERATOR/FREEZER		72	
• GALLEY		166	
• FOOD		933	1600
• DRY FOOD STOWAGE		35	70
• UTENSILS		38	51
TRASH MANAGEMENT	[ ]	[245]	[226]
• COMPACTOR		76	
• CANNISTER AND LINERS		169	226
RESTRAINTS AND HANDRAILS	[125]	[153]	[138]
• FOOT	38	53	38
• HAND	84	97	97
• STRAPS	3	3	3
HYGIENE FACILITIES	[325]	[ ]	[40]
• CHAMBER SINK & DRYER	60		
• SHOWER	90		
• COMMODE ASSY	145		
• EXPENDABLES	30		40
HOUSEKEEPING	[20]	[52]	[62]
• VACUUM CLEANER	20	20	20
• WIPES TOWELS		32	42

ASSEMBLY	WEIGHT (LBS) A/A	HAB	LOG.
FURNISHING	[329]	[776]	[217]
• PARTITIONS	78	130	–
• DOORS	6	18	–
• TABLES	-	21	–
• DESK	-	7	–
• BUNKS	-	153	–
• NOISE ATTEN MATERIAL	10	21	10
• LIGHTS	46	46	7
• PAINT	17	16	14
• STORAGE CONTAINERS	172	286	186
• WORKBENCH	–	64	–
• MISC	–	33	–
CREW EQUIPMENT	[582]	[1403]	[678]
• GARMENTS, BEDDING, ETC		433	650
• PERSONAL RESCUE SPHERE	-	78	–
• EVA SUIT	–	660	–
• CREW ACCESSORIES			
TOOL KITS	28	75	–
FIRE EXTINGUISHERS	8	16	8
• EMU	525	–	-
• PERSONAL HYGIENE	-	20	20
• MEDICAL KIT		20	–
• IVA MASK	21	21	-
• EXERCISE & REC KIT		80	-

Figure 6.16-8

BASIC MANNED PLATFORM WEIGHT

VFR200

(STRUCTURES, MECHANICAL, AND THERMAL CONTROL SYSTEM)

ASSEMBLY	WEIGHT (LBS) A/A	HAB	LOG
*STRUCTURE SYSTEM			
PRIMARY SHELL	[1268]	[5331]	[3453]
DOMES	266	1235	1235
CYLINDER SECTION	584	3019	1492
LONGITUDAL STRUT ASSY	185	187	187
KEEL ASSY		101	101
FLOORING	233	693	390
MISC		96	48
TUNNEL SHELL	[658]	[ ]	[782]
DOMES	151		159
CYLINDER SECTION	392		621
LONGITUDAL STRUT ASSY	115		
AIRLOCK	[800]	[ ]	[ ]
SECONDARY STRUCTURE	[510]	[932]	[1165]
RACKS	345	892	892
GRAPPLE FITTING	40	40	30
TANK SUPPORTS	125		233

ASSEMBLY	WEIGHT (LBS) A/A	HAB	LOG.
*MECHANICAL SYSTEM			
HATCHES	[587]	[216]	[261]
• INNER	45		45
• OUTER	542	216	216
BERTHING MECH	[1516]	[445]	[445]
• PASSIVE	238	119	119
• ACTIVE	1016	259	259
• UMBILICAL	262	67	47
*THERMAL CONTROL SYSTEM			
ACTIVE THERMAL CONTROL	[159]	[187]	
• WATER PUMP PACKAGE	28	28	
• COLD PLATES	36	54	
• LINES & DISCONNECTS	84	94	
• MISC	11	11	
PASSIVE THERMAL CONTROL	[206]	[449]	[447]
• MLI BLANKETS	89	426	424
• SUPPORTS ETC	117	23	23

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Figure 6.16-9

BASIC MANNED PLATFORM SYSTEM WEIGHT SUMMARY

VFR206

ELEMENTS	MODULE WEIGHT (LBS)					
	AIRLOCK ADAPTER		HABITABILITY		LOGISTIC	
STRUCTURE	3338		6263		5400	
PRIMARY SHELL		1268		5331		3463
TUNNEL SHELL		658		-		782
AIRLOCK		900		-		-
SECONDARY STRUCTURE		610		932		1106
MECHANICAL SYSTEM	2103		861		783	
HATCHES		587		216		261
BERTHING		1516		445		445
THERMAL CONTROL SYSTEM	386					
ACTIVE		130	636	187	447	-
PASSIVE		206		449		447
EC/LS	6125		1288		8025	
ATMOSPHERE STORAGE & CONTROL		2242		124		3340
ATMOSPHERE REVITALIZATION		978		1142		230
WATER MANAGEMENT		2906		20		4666
COMMUNICATION & DATA MANAGEMENT	881		633		9	
DATA MANGEMENT		615		416		5
TV		280		84		-
TIMING DISTRIBUTION		5		34		-
C&W/SAFING		36		34		-
VOICE COMMUNICATION		65		32		4
ELECTRICAL POWER	748		1398		410	
POWER DIST/CONVERSION		238		219		30
POWER CONTROL		8		77		-
WIRING		602		1103		380
HABITABILITY SYSTEM	1381		3472		3171	
FOOD MANAGEMENT		-		1244		1811
TRASH MANAGEMENT		-		245		226
RESTRAINTS & HANDRAILS		125		153		138
HYGIENE FACILITIES		325		-		40
HOUSEKEEPING		20		52		62
FURNISHING		329		775		217
CREW EQUIPMENT		582		1403		678
CONTINGENCY	1173		1382		1153	
TOTAL WEIGHT (LBS)	18112		18132		20333	

6.18 MINIMUM COST/EARLIEST CAPABILITY CONCEPT

There are many reasons for assuming that the Manned Space Platform (MSP) may have modest beginnings with gradual evolutionary growth to major operational service. Among such reasons are such realities as budget constraints and most probably, a gradual rather than spectacular increase in the availability of payloads which are specifically built for extensive manned involvement. For such reasons, it is interesting to consider an "earliest" phase of our recommended concept wherein only a central crew/adapter/haven-type module is flown with the 25 kW Space Platform, as illustrated in Figure 6.18-1. In the next figure (Figure 6.18-2), the interior layout is shown to include full accommodations for a crew of two for 90 days of flight plus 30 days of contingency sustainability. The features of this earliest system are shown in Figure 6.18-3.

This elemental capability could perform quite effectively for many weeks with two palletized science and applications payloads. But realistically, additional

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Figure 6.18-1

VFQ416

MINIMUM MANNED PLATFORM (2-MAN)

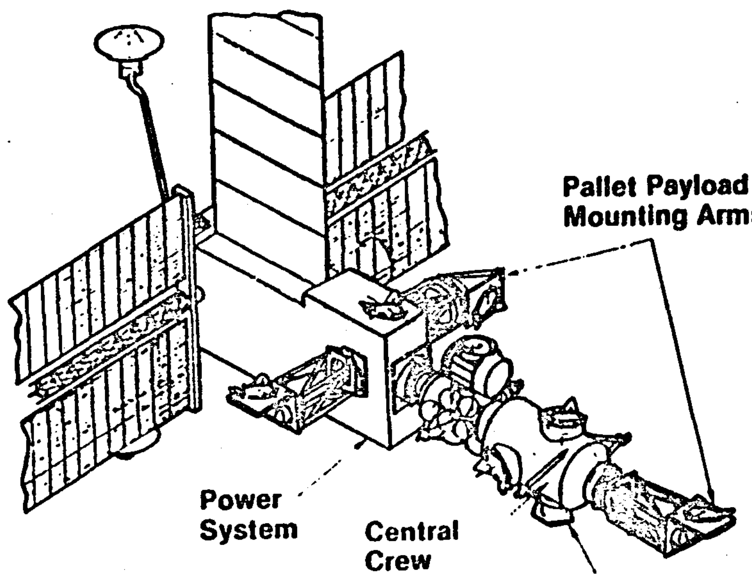

Figure 6.18-2

VFQ419

CENTRAL CREW MODULE/HAVEN

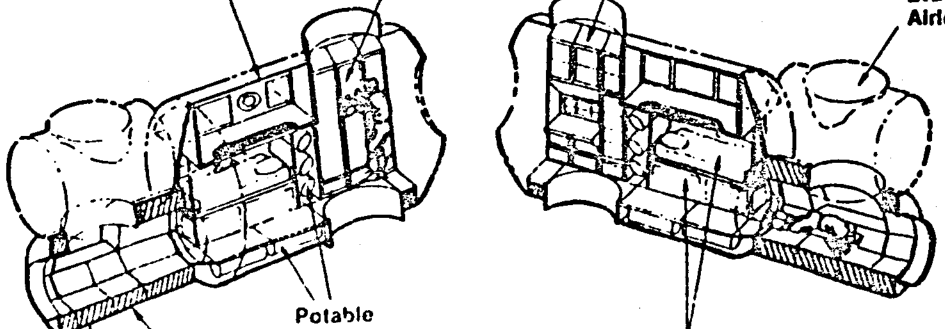

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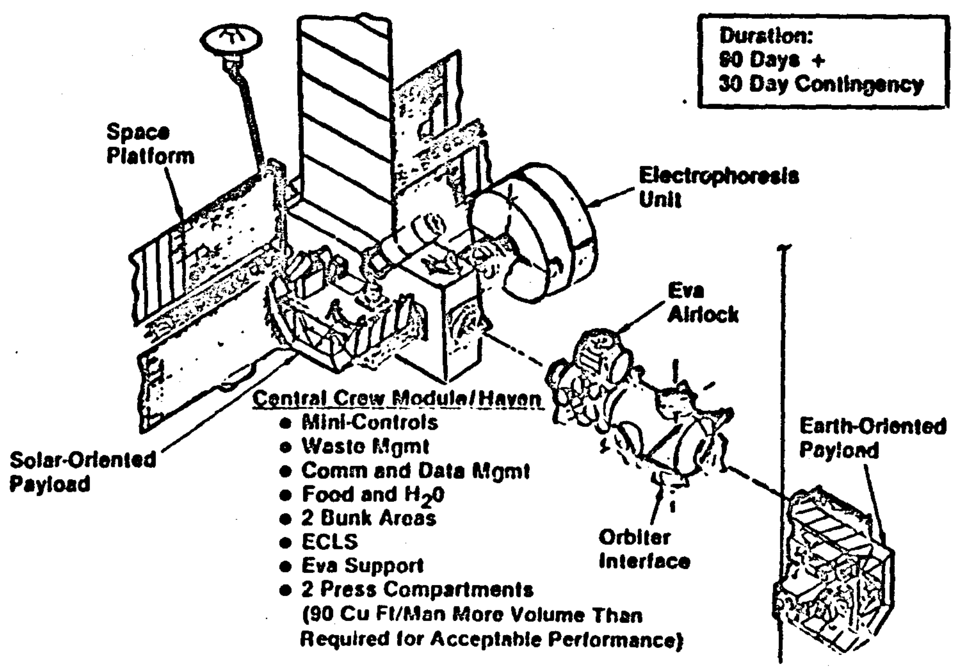
Figure 6.18-3

MINIMUM MANNED PLATFORM ELEMENTS AND CAPABILITIES



Volume is necessary for months of flight and can be provided by the 180-day replaceable logistics module, another key element of our Manned Platform; added as soon as possible, as shown in Figure 6.18-4.

Now then, we have a capability comparable to the Salyut 6 of the USSR (shown in Figure 6.18-5) (comparison shown in Figure 6.18-6). Six Salyuts have logged over 10 years in space with a routine crew of two, but during crew exchanges has accommodated as many as four. Salyut also has an unmanned resupply vehicle called Progress. Routine crew exchanges are accomplished with the Soyuz vehicles. Salyut has performed a considerable variety of civilian and military payload activities which attests to the broad capabilities inherent in only a two-man system.

Therefore, with only the combination of our central crew/adapter/haven and a logistics module, a significant and internationally competitive addition to the U.S. inventory of manned space capabilities can be provided.

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Figure 6.18-4

MINIMUM MANNED PLATFORM WITH RESUPPLY

VFO418

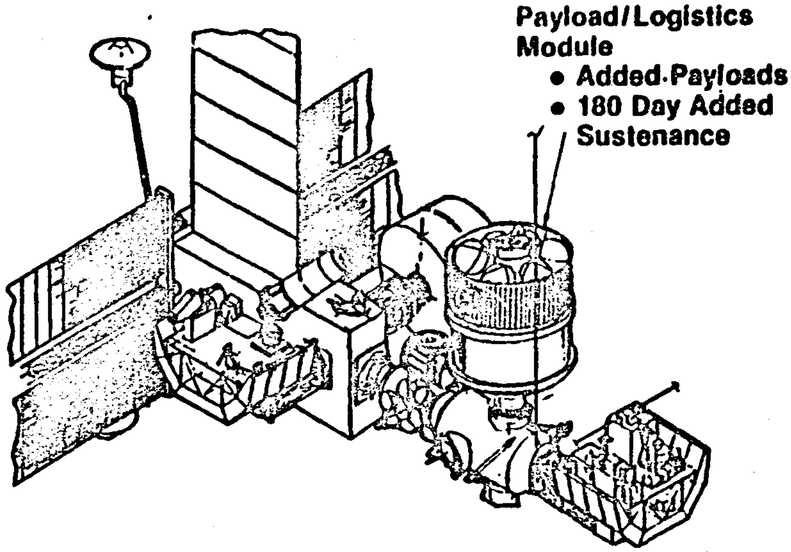

Figure 6.18-5

SALYUT 6 SPACE STATION
(19,000 KG, CREW OF 2-4)

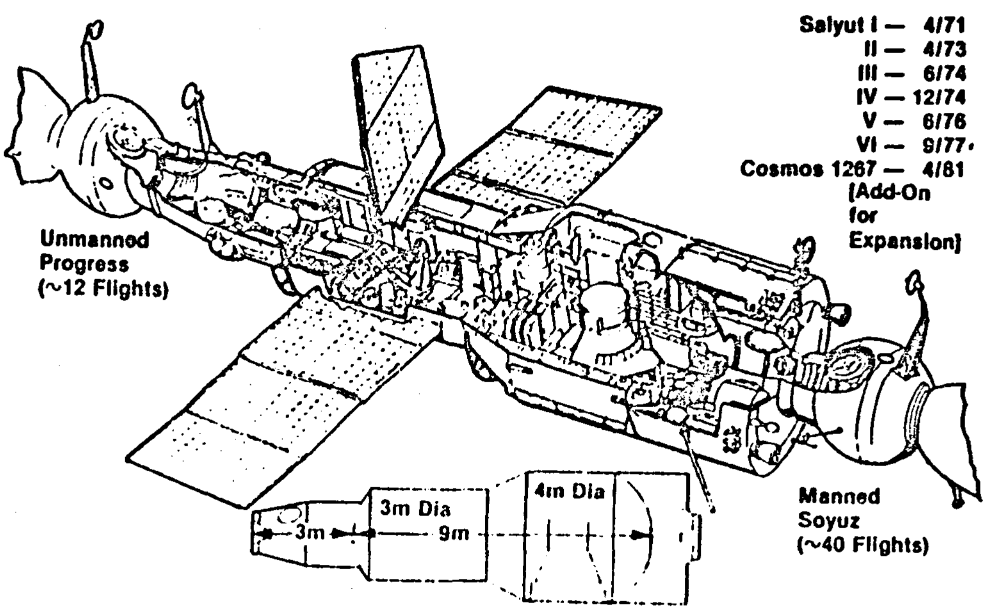

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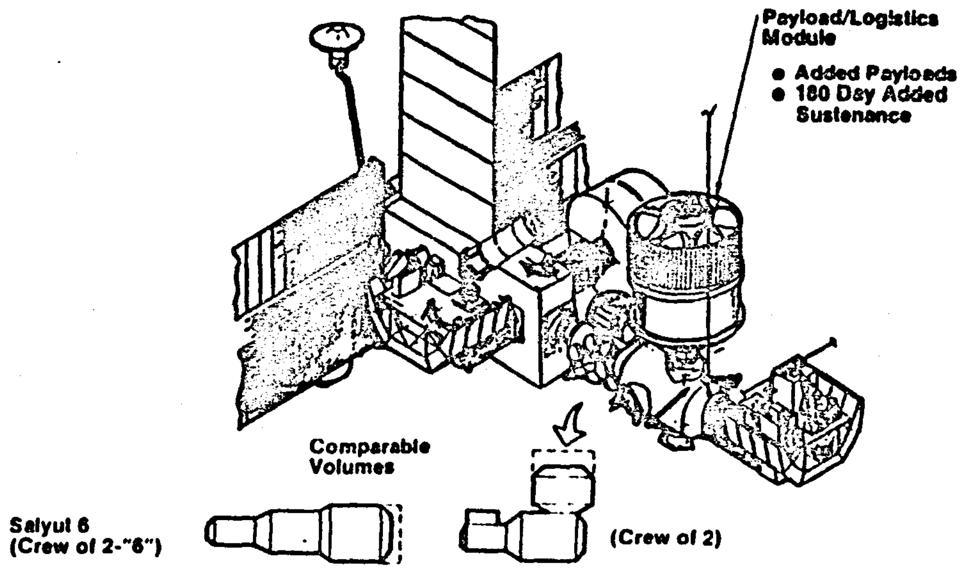
Figure 6.18-6

MINIMUM MANNED PLATFORM WITH RESUPPLY (RELATED DATA)

VFO436



Section 7
TECHNOLOGY ADVANCEMENT

Technology for the type of system in prospect here must be addressed in two categories, namely:

- Accommodation, sustenance and protection of man
- Innovative utilization of man with machines in space

Because of the technology developed on Skylab and Shuttle much of the basic technology exists for the accommodation, sustenance and protection of man for long periods in orbit. However, for a given new vehicle configuration and for the application of new technology developed for the 80s, certain technology programs must be initiated to assure maximum performance and safety in any new system.

Therefore, as shown in Figure 7-1, there are two categories of technological advancement recommended for the manned space platform, namely:

- Enhancement of basic manned system capability
- Enablement of advanced manned capabilities

Figure 7-1

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TECHNOLOGY FOR THE EVOLUTIONARY MANNED PLATFORM

Enhancement of Basic Manned System Capability

- Command and Data Management
  - Fault-Tolerant Computers
  - Fiber Optic Data Bus
- Power Distribution
  - Remote-Control Breakers
  - Rotating Interfaces
- Environmental Control and Life Support
  - Regenerative Carbon Dioxide Control
  - Wastewater Recovery
- Attitude Control
  - Manned Motion Isolation
  - Large Momentum Storage and Desaturation
- Unmanned Logistics
- EVA Services

Enablement of Advanced Manned Capabilities

- Large Structures
  - Deployment
  - Assembly
  - Alignment
- Orbital Transfer Vehicle Basing
  - Propellant Storage
  - Propellant Handling
  - Payload Integration
  - Checkout/Launch
- Servicing
  - All of the Above
  - Spacecraft
- Remote Vehicle Retrieval/Control
  - All of the Above

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The types of "Enhancement" items are described in Paragraph 7.1 below, whereas the "Enablement" terms are covered in Paragraph 7.2.

7.1 ENHANCEMENT TECHNOLOGY ITEMS

7.1.1 Command and Data Management

Fault Tolerant Computer Systems

The development of hardware techniques, software techniques and system architecture concepts for fault tolerant data processing would enhance the performance and reliability of manned platforms and would decrease the life cycle costs. System concepts whould consider on-orbit reconfiguration requirements. DoD Very High Speed Integrated Circuit (VHSIC) and commercial VLSI developments should be incorporated.

Fiber Optic Data Bus

Development of fiber optic data bus hardware techniques and bus architecture concepts would enhance the manned platform internal data distribution capability and could decrease RFI susceptibility, weight and acquisition costs. Emphasis needs to be placed on developing reliable connectors and couplers.

7.1.2 Electrical Power Distribution

Space-qualified remote-control circuit breakers/power controllers which have low voltage drop and operating power and high current interrupting capability would enhance high voltage (100-300V) and low voltage (nominal 30V) distribution efficiency.

Power transfer devices (rotating interface) exhibiting lightweight, low loss and high power capability would enhance long life, high reliability applications.

7.1.3 Environmental Control and Life Support

Regenerative Carbon Dioxide Control System would enhance the capability to operate with or without O_2 recovery, minimization of power and cooling requirements. The primary candidate approach for this is solid amine-water desorbed.

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Waste Water Recovery System would enhance the capability of recovering potable water from urine, condensate and hygiene water; it would minimize power and cooling. The prir..ry candidate approaches are Thermoelectric Integrated Membrane Evaporation System (TIMES) and Vapor Compression Distillation (VCD).

7.1.4 Attitude Control

Manned module motion/force isolation system would enhance isolation of the Platform from man-induced disturbances. This would allow for better pointing and low-g per-ormance for payload mounted on the Platform along with manned operations. Magnetically levitated joints might be a good path to pursue. Power, data, communication and fluid transfers across the joint would be required.

Large integrated momentum storage/energy storage systems and magnetic torquer technology (large momentum storage and magnetic momentum desaturation systems) would enhance orientation flexibility and for future growth configurations. The momentum storage function may also be integrated with an energy storage system to reduce battery requirements by using the stored kinetic energy in the spinning wheels.

7.1.5 Logistics

Future manned spacecraft would benefit considerably from an unmanned contingency logistics vehicle capable of being launched by an expendable-type launch system in between or in emergencies instead of Shuttle flights.

7.1.6 EVA

Demonstration of man's capability to assist in the erection, assembly and maintenance of large orbiting space systems must be developed.

7.2 ENABLEMENT TECHNOLOGY AREAS

New developments are required in these areas in order to enable industry to produce reliable hardware.

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7.2.1 Large Structures

Payloads in the 1990s will require large reflectors for infrared, communications, radar, gravity wave sensing and particle beam injection. The deployment and/or assembly of such large structures is a new technology and will require development and orbital testing of unique support equipment, tools and techniques. Once erected the rigidization and alignment of such structures will also require development of distributed-force units, deflection sensors, laser surface form scanners, etc.

7.2.2 Orbital Transfer Vehicle (OTV) Basing

OTV storage, refueling, checkout, launch, recovery and berthing on an orbital base involves many new technologies. Some of these are most effectively on-orbit and therefore, related experiments will be performed on the manned platform as a precursor step to OTV hardware and base equipment production and operations.

7.2.3 Spacecraft Servicing

This future utilization area for the manned space platform involves various servicing specialists, tools, accessory equipment, instrumentation and a diagnosis/relaunch control center. Moreover, it involves the operation of an inter-orbital, two-way stage or teleoperator maneuvering system to transfer and dock to and return the spacecraft from some orbit, perhaps quite remote from the manned space platform. Here again, numerous technology experiments should be developed and tested on-orbit in the actual operating environment before system designs are finalized.

7.2.4 Remote Vehicle Retrieval/Control

There is an entire spectrum of missions which involve the excursion and recovery of or special operations support equipment or payloads away from the manned space platform. This involves various technologies which also require experimental flight testing in orbit to assure that an accurate comprehension of real operating conditions and constraints exists before the system design is finalized.

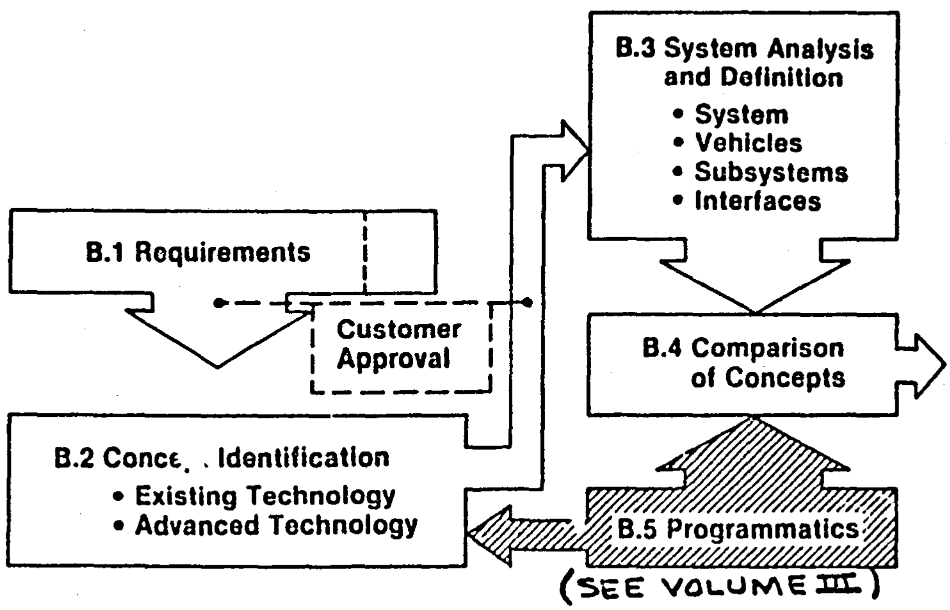
Section 8

PROGRAMMATICS (SUBTASK B.5)

This subject is covered in a separate volume, III, and related to the other subtasks covered in this volume, as shown in Figure 8-1.

Figure 8-1

TASK B — MANNED PLATFORM CONCEPT



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Appendix B
ACRONYMS

A/A	Airlock/Adapter
ACS	Attitude Control Subsystem
A/D	Analog to Digital
AFD	Aft Flight Deck
ARS	Atmosphere Revitalization Subsystem
ASCS	Atmosphere Supply and Control Section
ASTP	Apollo/Soyuz Test Project
BU	Branching Unit
CB	Circuit Breaker
CDMS	Communication and Data Management Subsystem
CMG	Control Moment Gyro
C&W	Caution and Warning
D/A	Digital to Analog
DDU	Data Display Unit
DMS	Data Management Subsystem
EDC	Electrochemical Depolarizer Concentrator
ECLS	Environmental Control/Life Support
EMU	Extravehicular Mobility Unit
EPDS	Electrical Power Distribution Subsystem
EPS	Electrical Power Subsystem
EPSP	Experiment Power Switching Panel
ESA	European Space Agency
EVA	Extravehicular Activity
FM	Frequency Modulated
FMDM	Flexible Multiplexer Demultiplexer
GMT	Greenwich Mean Time

HDRR	High Data Rate Recorder
H/M	Habitability Module
HRM	High Rate Multiplexer
HX	Heat Exchanger
I/O	Input/Output
IOP	In the Orbit Plane
IVA	Intravehicular Activity
KB	Keyboard
LRU	Line Replaceable Unit
LTM	Launch Test Module
LV	Local Vertical
MDM	Multiplexer Demultiplexer
MET	Mission Elapsed Time
MMU	Mars Memory Unit
MOI	Moment of Inertia
MSP	Manned Space Platform
MTBF	Mean Time Between Failures
OPF	Orbiter Processing Facility
OTV	Orbital Transfer Vehicle
OWS	Orbital Workshop
PCB	Power Control Box
P/L	Payload
POP	Perpendicular to the Orbit Plane
PS	Power System
PSL	Perpendicular to Sunline
PRS	Personal Rescue System
RAU	Remote Acquisition Unit
RCS	Reaction Control System
RF	Radio Frequency
RMS	Remote Manipulator System

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SASP	Science and Applications Space Platform
SAWD	Solid Amine Water Desorbed
SI	Solar Inertial
SL	Spacelab
SP	Space Platform
SPDB	Subsystem Power Distribution Box
S/S	Subsystem
SRB	Solid Rocket Booster
STACC	Standard Telemetry and Control Components
TCS	Thermal Control Subsystem
TDRSS	Tracking and Data Relay Satellite System
TIMES	Thermoelectric Integrated Membrane Evaporation Subsystem
TMS	Teleoperator Maneuvering System
TV	Television
VCD	Vapor Compression Distillation
VHSIC	Very High Speed Integrated Circuits
VLSIC	Very Large Scale Integrated Circuits
VRCS	Vernier Reaction Control Subsystem
VV	Velocity Vector

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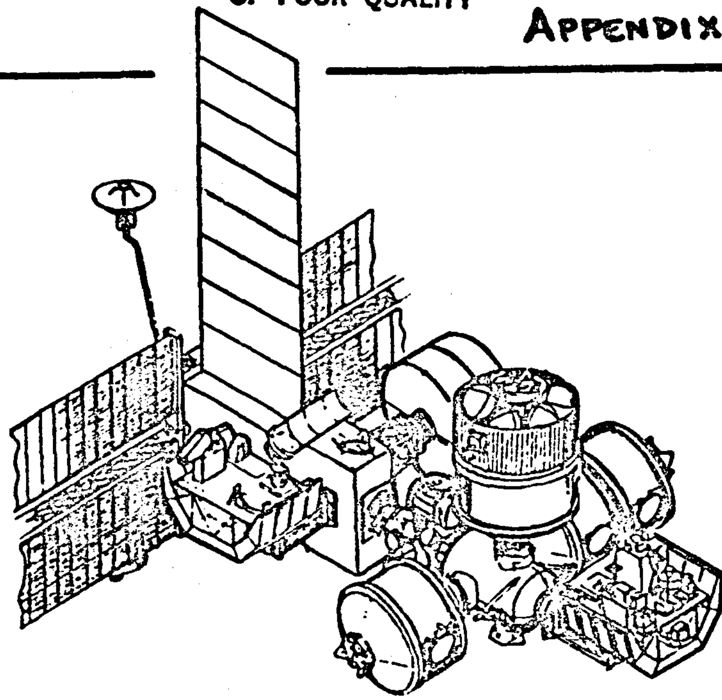
APPENDIX C



MANNED SPACE PLATFORM

Design Guidelines and Criteria

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TABLE OF CONTENTS

1.0 MANNED SPACE PLATFORM PROGRAM GENERAL REQUIREMENTS

1.01 The Manned Space Platform (MSP) is a permanently-manned facility operating in low Earth orbit and used for operational support of Space activities such as Scientific research, on-orbit assembly, servicing of Space vehicles and assembly/checkout of large Space systems. Resupply shall be via the Space Shuttle. Modules and/or equipment shall be transported to and from low Earth orbit (LEO) internal to the Space Shuttle. The MSP will be capable of growth from an initial configuration capable of supporting up to three (3) personnel in a permanently manned mode to a growth configuration capable of supporting up to six (6) crewmen.

1.02 The configuration approach shall minimize the number of Shuttle launches required to fully establish an operational Manned Space Platform.

1.03 The development approach will provide for reducing the number and cost of test articles and major tests and will provide for utilization of the Orbiter for on-orbit testing.

1.04 "Commonality" is a primary consideration throughout the study. As a goal, common module structures, subsystems, and mission hardware will be developed.

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2.0 PLATFORM GENERAL REQUIREMENTS

2.01 The Manned Space Platform (MSP) shall be capable of use in a LEO range of 28.5° to 104° inclination at an altitude between 370 km (200 nm) and 740 km (400 nmi). (Provisions for modifications to allow higher altitude operational shall be retained.)

2.02 The initial Manned Space Platform will be fully operational when it has the capability of being continuously manned. To be continuously manned, the MSP will have capability for environmental control and life support, electrical power, stabilization and control, guidance and navigation, communications, thermal control, and data management for a period of 90 days plus without resupply.

2.03 The "design to" weight of Shuttle transported modules shall not exceed a maximum of 29,485 kg (65,000 lbs). The nominal Orbiter payload weight for planned landing shall not exceed 14,515 kg (32,000 lbs).

2.04 The maximum external dimensions of the modules shall be 4.42m (14.50 ft) in diameter and 17 m (56 ft) with planned EVA or 18.25 m (60 ft) without planned EVA, in length. Mechanisms that are external but attached to the module, such as handling rings, attachments for deployment docking mechanisms, storage fittings, etc., shall be contained during launch within a dynamic envelope of 4.6 m (15 ft) diameter and 18.25 m (60 ft) length.

2.05 Space Shuttle System Payload Accommodation, JSC 07700, Volume XIV, Revision G, Change No. 33, dated 26 September 1980, Volume III, Flight Operations; Volume IX, Ground Operations; and Volume X, Flight and Ground System Specifications shall be the reference for performance and required interface data.

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2.06 The Manned Space Platform shall be capable of accommodating a mixed male-female crew (5th to 95th percentile).

2.07 Payload and habitability modules of the Platform shall be replaceable without major activity disturbance.

2.08 The MSP shall be capable of operating in an unmanned mode up to four months (both initially and in an abandoned mode).

2.09 The initial MSP shall have the capacity for independent operation with the full crew for a period of at least 90 days in LEO.

2.010 At least 30 days consumables, including those for habitability and mission objectives shall be available beyond the scheduled resupply missions.

2.011 The MSP shall be capable of operating in both single and multiple shift modes.

2.012 In general, day-to-day planning of activities shall be performed onboard; long-range planning shall be performed on the ground.

2.013 Crew transfer from the Orbiter to the MSP (manned or unmanned) shall be performed in a shirtsleeve environment.

2.014 The initial MSP will be sized to accommodate at least 3 crewmen. Provisions for double occupancy will be provided in cases requiring exchange crew overlap periods that exceed the Orbiter's accommodations. The maximum crew overlap will be (3) crewmen for (7) days.

2.015 A minimum of two separate pressurized habitable volumes with independent life support capability and habitability provisions will be provided at each manned stage of the Manned Space Platform buildup and operation.

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2.016 Each separate habitation volume shall have an EVA route to support rescue.

2.017 The MSP shall provide for an Orbiter and module berthing capability. In addition, an alternate emergency berthing capability for the Orbiter, shall be available. The MSP berthing provisions shall accommodate crew transfer, logistics flights, and module additions/removals.

2.018 Solid wastes shall not be dumped to Space.

2.019 Commonality is to be a primary consideration. The various modules shall use common structural assemblies/subassemblies, subsystems, components and mission hardware as much as practical to reduce costs.

2.020 All hardware associated with the MSP will be designed, and prelaunch operations will be developed, so as to require minimum access to the module while in the Orbiter cargo bay.

2.021 For the initial MSP, all crew members of each MSP crew shall be qualified for EVA, and EVA provisioning for all crew members is required. Personal Rescue Systems (PRSs) and provisions will also be provided for the crew.

2.022 Berthing ports and hatches shall be sized for a minimum 40-inch opening and shall provide interfaces for air, water, power, data bus, etc. Primary access routes shall accommodate package volume sizes of (TBD) inches. Secondary access routes shall accommodate package volume sizes to (TBD) inches. Primary access is defined as a "trunk line" throughout the MSP connecting all major elements. Secondary access routes are defined as those that are parallel to or in addition to primary routes such as access to crew quarters, galley, film developing lab, etc.

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2.023 At each phase of the on-orbit assembly sequence, the Orbiter and/or onboard crew shall have the capability and resources to checkout and validate the operation of the MSP.

2.024 System design shall accommodate variations in the MSP configuration due to buildup and multiple operations conducted simultaneously, such as on-orbit assembly, berthing, and payload servicing.

2.025 The MSP configuration shall provide operational flexibility and reasonable avenues for growth.

2.026 The MSP shall provide any necessary interface capability with the Orbiter subsystems during Orbiter-tended operations.

2.027 The MSP shall normally fly at an altitude such that its orbit lifetime is at least 90 days without orbit makeup. Any orbit makeup shall be provided via the Power System reboost module.

2.028 The measure to prevent uncontrolled deorbit (unmanned mode) shall be a controlled deorbit. Accordingly, the Power System propulsion system shall always be maintained to accomplish a deorbit from 200 nm.

2.029 The first module(s) to be orbited shall provide the following communications:

a. telemetry/commands (uplink and downlink)
b. metric tracking (GPS)
c. and when manned, duplex voice links
d. communications distribution interfaces.

Subsequent attached modules can rely on the first module for these communications.

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2.1 SAFETY REQUIREMENTS

2.1.1 For emergency conditions, the following capabilities shall be provided:

- o Rescue by the Orbiter in 180 hours (LEO only).
- o Isolation of any module containing hazardous/toxic materials from the remainder of the MSP within 90 seconds.
- o Rescue of entire MSP crew from an isolated module.

2.1.2 Critical onboard subsystems shall be designed to minimize risk of loss of modules, injury to the crew or damage to the Orbiter and other vehicles (fail operational/fail safe).

2.1.3 The MSP shall provide the capability for performing critical functions at a nominal level with any single component failed or with any portion of a subsystem inactive for maintenance.

2.1.4 The MSP shall provide the capability to perform critical functions at a reduced level with any credible combination of two component failures, or with any credible combination of a portion of a subsystem inactive for maintenance and failure of a component in the remaining portion of the subsystem.

2.1.5 Capability shall be provided for performing critical functions at an emergency level until the affected function can be restored or the crew returned to earth:

a. With any one module inactivated or isolated and vacated due to a malfunction or accident.

b. With any credible combination of a subsystem inactivated as a result of an accident and a portion of a redundant back-up system inoperative.

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2.1.6 For those malfunctions which may result in time-critical emergencies, provision shall be made for the automatic switching to a safe mode of operation and for caution and warning of crew members.

2.1.7 Capability shall be provided for extinguishing any fire in the most severe oxidizing environment prior to failure of primary structural elements. Interior walls and secondary structure shall be self-extinguishing.

2.1.8 All continuous nonmetallic materials shall be self-extinguishing in the most severed oxidizing environment to which they will be exposed. Means shall be provided for fire proof storage of medical supplies, maintenance supplies, food, tissue, clothing, trash, and for other non-self-extinguishing items, where they are in use.

2.1.9 Materials used in the habitable areas shall not outgas toxic constituents in the lowest pressure environments to which they will be exposed.

2.1.10 Personnel escape routes shall be provided in all hazardous situations. A design goal shall be to provide alternate escape routes that do not terminate into a common module area.

2.1.11 The Environmental Control/Life Support subsystem shall have the capacity for one repressurization of any one module independent of remaining modules.

2.1.12 The atmospheric constituents, including harmful airborne trace contaminants and odors, will be monitored and controlled in each pressurized habitable volume.

2.1.13 Provisions shall be made for detecting, containing (i.e., confining), and controlling (i.e., restoring to a safe condition) emergencies such as fires, toxic contamination, depressurization, structural damage, etc.

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2.1.14 Potentially explosive containers such as high pressure or volatile gas storage containers shall be placed outside of and as remotely as possible from personnel living and operating quarters. The containers shall be isolated and protected so that failure of one will not propagate to others.

2.1.15 Redundant equipment, lines, cables, and utility runs which are critical for safety of personnel or continued facility operation shall be either relocated and routed in separate compartments (i.e., separated by a structural wall) or protected against fire, smoke, contamination, overpressurization, and shrapnel.

2.1.16 Emergency EVA/IVA hardware (Extravehicular Mobility Unit "EMU" and Personal Rescue System "PRS") shall be readily accessible from within each pressure isolatable volume.

2.1.17 Deployment and initiation of operations considered hazardous shall be checked out from a safe location before exposing crewment to potential hazards.

2.1.18 All EVA shall be conducted either using the "buddy" system or within visual range of a suited crewmen at the workstation airlock ready to exit.

2.1.19 Provisions shall be made to return crewmen to the MSP Habitability Module who are incapacitated while performing EVA.

2.1.20 Provisions shall be made for the containment and/or disposal of toxic contaminants.

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2.1.21 The MSP shall be capable of operating with all critical functions performed within specified values following one component failure or any portion of a subsystem inactive for maintenance. This condition shall continue until maintenance can be performed.

2.1.22 The capability shall be provided for crew survival for at least 180 hours in LEO to permit restoration of operations or rescue of the crew by emergency Orbiter berthing following any credible combination of component failures and portions of a subsystem inactive for maintenance or any credible accident (e.g., loss of any pressure isolatable volume) and any single component failure.

2.1.23 The MSP (during buildup-premanning) shall be capable of being manned (shirtsleeve or IVA) for performance of maintenance tasks following any one component failure.

2.1.24 Subsystem or component failures shall not propagate sequentially. Equipment shall be designed to be fail operational/fail safe.

2.1.25 All critical life limited components and subsystems shall be designed to allow ground and on-orbit inspection.

2.1.26 Equipment or material sensitive to contamination shall be handled in a controlled environment. Fluids and materials shall be compatible with the combined environment in which they are employed. Process specification shall be formulated to prescribed handling and application methods.

2.1.27 Loss of redundancy for critical functions shall be detectable (automatically by the information subsystem and the crew).

2.1.28 Redundant paths, such as fluid lines, electrical wiring, and connectors, shall be located so that an event which damages one path is not likely to damage the other.

2.1.29 Conservative factors of safety shall be provided where critical single failure point modes of operation cannot be eliminated (pressure vessels, pressure lines, valves, etc.).

2.1.30 The allowable radiation limits for the crew are listed below.

LIMIT DOSE (REM)

	Depth	Daily*	30 Day	Quarterly**	Yearly	Career
Skin	(0.1MM)	0.6	75	105	225	1200
Eye	(3.0MM	0.3	37	52	112	600
Marrow	(5.0CM)	0.2	25	35	75	400

* one-year average

** May be allowed for two consecutive quarters with six months restriction from further exposure to maintain yearly limit. These limits apply to all sources of radiation exposures; therefore, design allowance for radiation exposures from the trapped radiation belts should not exceed 60 percent of these limits to provide a "cushion" for unexpected exposures (solar flares) and mission related (experiment) sources.

Radiation doses which affect personnel safety must be considered from all sources, including natural environment, external isotope and reactor sources, if any, microwaves, and solar cosmic radiation.

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2.2 MAINTAINABILITY REQUIREMENTS

2.2.1 Maintenance and repair shall be performed on-orbit to the (TBD) level.

2.2.2 MSP shall provide assistance for fault isolation and subsystem checkout. Fault isolation and subsystem checkout will be performed in flight by reduction of onboard stored and dumped data.

2.2.3 Subsystem design shall include Built-in-Test (BIT) capability to facilitate detection and reporting of functional discrepancies. As a minimum, this BIT capability shall enable failure detection at a functional path level in flight along with fault isolation. BIT will be implemented by utilizing continuously monitoring built-in-test-equipment, externally controlled self-test circuitry (self-test), and/or by providing adequate test point information at the electrical interfaces. Built-in-Test Equipment shall be provided for all time critical equipment.

2.2.4 The checkout method utilized will provide the following:

a. Failure detection of operational failure modes.
b. External initiation of self-test circuitry.
c. Status of redundant functional paths in the station.
d. Indicated corrective action.

2.2.5 Subsystems equipment shall be compatible with the onboard checkout subsystem and allow removal or replacement by using installation-handling devices and the onboard tool kit. The interconnecting plumbing and wire runs shall have suitable attachment, length, and mounting characteristics to facilitate removal.

2.2.6 The onboard checkout subsystem shall be able to isolate faults to specific modularized subsystems. These subsystems, similar to the line-replaceable units in the Orbiter, may be further subdivided into submodule units, which can be isolated and replaced at the workbench level of maintenance.

2.2.7 As a goal, all walls, bulkheads, hatches, and seals whose integrity is required to maintain pressurization shall be readily accessible for inspection, maintenance, or repair by shirtsleeved crewmen.

2.2.8 Inspection, maintenance, and repair of berthing assembly mechanisms by shirtsleeved crewmen shall be a design goal.

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2.3 RELIABILITY REQUIREMENTS

2.3.1 The system design goal of the MSP shall be such that no single credible failure or credible combination of failures endanger the life or safety of crewmembers or result in crew abandonment of the Platform during any normal or contingency operating mode.

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3.0 INTERFACE ADAPTER/AIRLOCK MODULE

3.1 General Requirements

3.1.1 The Interface Adapter/Airlock Module (A/A) shall be the first MSP module delivered to LEO.

3.1.2 The module shall provide a shirtsleeve environment to permit transfer of crew, equipment and supplies between the Orbiter, MSP and berthed pressurized payload modules.

3.1.3 The module shall incorporate at least five (5) berthing ports and one (1) port to accommodate the Orbiter. The Orbiter interface port shall be located so that the Orbiter can dock/berth to this position with tail clearance under maximum misalignment conditions.

3.1.4 The module shall provide a passive berthing interface compatible with the Power System berthing mechanism.

3.1.5 The module shall provide a passive berthing interface compatible with the Space Shuttle Docking/Berthing System.

3.1.6 The Adapter/Orbiter interface shall incorporate, but not be limited to the following:

FUNCTIONS	TYPE CONNECTOR	NUMBER OF CONNECTORS	TOTAL CONNECTOR FUNCTIONS
POWER	IN-FLIGHT DISCONNECT RECEPTACLE	3	12 PINS (#0 GA.) (4/CONNECTOR) - 30 VDC POWER 30 PINS (#22 GA.) (10/CONNECTOR) - POWER COMMANDS, DATA
COMMAND/DATA	IN-FLIGHT DISCONNECT RECEPTACLE	3	21 PINS (COAX) (7/CONNECTOR) - HIGH RATE DATA, CLOCK, TIMING 156 PINS (#20 GA.) (52/CONNECTOR) - LOW RATE DATA, COMMANDS, DISCRETES
THERMAL	1/2" DIA. QUICK DISCONNECT	4	2 - FREON SUPPLY 2 - FREON RETURN

3.1.7 The module is to provide the means of transfer from a shirtsleeve environment of the MSP to the vacuum environment of Space and contain the pressurization and depressurization systems necessary to effect the transition.

3.1.8 The module shall incorporate one (1) EVA airlock. (The Orbiter airlock is the preferred configuration.)

3.1.9 Support systems for routine EVA, suit donning/doffing, suit checkout, recharging, drying, and suit repair shall be performed in the Adapter area adjacent to the EVA airlock.

3.1.10 The Adapter/Airlock module shall incorporate the atmospheric supply system for MSP initial build-up period and for 90 days duration between resupply missions, plus 30 days of emergency usage.

3.1.11 An atmospheric purification source for CO_2 control, trace contamination, odor and humidity control shall be provided for the module volume.

3.1.12 A communications intercom station shall be provided.

3.1.13 Normal and emergency lighting shall be provided.

3.1.14 The module shall be sized for emergency food and water supply to support three (3) crewmen for 30 days.

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3.1.15 An emergency vent capability shall be incorporated.

3.1.16 The adapter module shall incorporate the MSP water supply system with umbilicals to all MSP module interfaces.

3.1.17 Umbilical design for all MSP module interfaces shall be identical to permit inter-changeability.

3.1.18 Berthing/Docking ports shall have a 40-inch diameter clear opening and designed to accept a "D"-shaped hatch similar to the Orbiter Airlock hatch.

3.1.19 Electronic switching subsystems and devices are to be located in the adapter to direct services to the various interfaces.

3.1.20 The following elements/subsystems shall be attached to the exterior of the Adapter/Airlock module:

a. Gaseous O_2 storage
b. Gaseous N_2 storage
c. TV camera
d. EVA handolds and maitnenance fixtures
e. Life support umbilical connectors

3.1.21 The capability for rapid depressurization and repressurization of the EVA/IVA airlock is required. This rate is not to exceed 1 psi/sec. Depressurization control should be possible from inside and outside the module as well as from inside the airlock. Repressurization control shall be possible from both inside the module and inside the airlock.

4.0 HABITABILITY MODULES

4.1 GENERAL REQUIREMENTS

4.1.1 The MSP interior design shall orient all compartments, facilities, cabinets, experiments and equipment utilized by the crew in an unidirectional (one-g) configuration. Deviation from the single direction orientation shall be 90°. All items that are oriented 90° from the established normal shall be in one direction of rotation to prevent any two items with a 180° opposition angle.

4.1.2 All equipment for a given task shall be grouped together to facilitate task accomplishment and minimize crew time.

4.1.3 All work stations shall conform to a basic common design with modifications only as required to accommodate unique requirements of a particular work station.

4.1.4 The MSP shall provide private sleeping quarters for the nominal crew of three crewpersons.

4.1.5 The sleeping quarters provided for each of the normal MSP crew shall be basically equal, though not necessarily identical.

4.1.6 The MSP shall contain appropriate provisions and compartmentation for at least the following:

- Up to (3) individual crew quarters per habitation module.
- Galley
- Personal hygiene
- Exercise area
- ECLSS - Up to (3) crewmen per ECLSS unit
- Housekeeping provisions
- Waste management compartment
- Stowage and maintenance provisions
- EVA/IVA communications provisions

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- Command/control center
- Work stations
- Microbial monitoring
- Contaminate gas monitoring

4.1.7 The MSP shall provide adequate personal hygiene systems for washing in each habitability module. A shower is not required; however, the module interior design shall not preclude the addition of a shower facility at a later time.

4.1.8 The MSP shall provide adequate private waste mangement facilities for feces, urine and vomitus collection and disposal for the nominal crew of three (3) crewpersons. Privacy and isolation from sleep and galley areas are prime design considerations.

4.1.9 The waste management facility shall be designed for male and female crew acceptance.

4.1.10 Food Management System - the food management equipment shall provide for the storage, preparation, consumption of food, and collection of food waste and debris.

4.1.10.1 Food System - The food types supplied for the MSP crew shall be separated as follows:

a. Beverages (powders or crystals to be reconstituted from water)
b. Rehydratable foods (foods to be reconstituted from water).
c. Thermostabilized Foods (normal moisture foods, heat processed to prevent spoilage)
d. Frozen foods (normal moisture foods, frozen to prevent spoilage)
e. Wafer Food (ready-to-eat snack type foods)

4.1.10.1.1 The MSP shall provide the following food rations:

a. Normal rations

- 3.6 lb/man-day of shelf-stable food (includes food, water in the food and packaging)
- 1.0 lb/man-day of frozen food (includes food, water in food and packaging)
- 5.5 lbs of water/man-day (1.5 lb man-day for drinking, 4.0 lbs/man-day for food rehydration)
- 10 lb/ft^3 for frozen/refrigerated food
- 14 lb/ft^3 for shelf-stored food

b. Contingency rations

- Contingency rations shall be the same food as normal rations except as noted below:
  - 2.06 lb/man-day (shelf staples) for 30 days
  - 5.5 lbs of water/man-day

4.1.10.2 Food Preparation Equipment - The MSP shall provide, as a minimum, the following food preparation equipment:

a. Freezer (10°F) and refrigerator (40°F)
b. Serving equipment (trays, dispensers for beverages, eating utensils, etc.
c. Oven
d. Hot water supply (140°F)
e. Cold water supply (45°F)

All food preparation equipment shall be located in the same general area to minimize crew time and effort in the preparation of meals.

4.1.10.3 Food Storage and Resupply - The food shall be stowed in a manner so that each type of food is readily accessible and should be grouped by items, i.e., all beverages, desserts, etc., rather than by individual meals.

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4.1.10.3.1 Food shall be packaged and stored in meal-size portions for individual crewmen.

4.1.10.3.2 Provisions shall be made for stowage of usable leftover food (the refrigerator is acceptable for this purpose).

4.1.10.3.3 The design of food storage equipment and supplies, in resupply areas, shall utilize a standardized module to facilitate the resupply of food in the food preparation area.

4.1.10.3.4 Food storage shall be distributed between the pressurized modules such that there will always be sufficient contingency food available if one food storage location is evacuated and resupply is not available for 90 days.

4.1.11 The MSP shall provide a trash management system. A trash compactor shall be provided for compacting food-related and other trash. Suitable packaging and storage for compacted waste shall be provided.

4.1.11.1 Trash collection provisions shall be located in areas where it is anticipated that high trash generation will occur.

4.1.11.2 Vacuum cleaning should be provided to and in removal of accumulated debris and free water from the atmosphere. The function includes spilled vomitus, solids, particulate matter, liquids on surfaces and dirt.

4.1.11.3 Microbiologically contaminated waste material shall be disinfected as close as possible to its source prior to storage, processing, or disposal.

4.1.12 The MSA shall provide medical treatment provisions similar to the Space Shuttle medical systems with appropriate changes in supplies and equipment based on anticipated medical conditions and requirements.

4.1.13 The MSP shall have command/control facilities located in the habitability module near the crew commander's sleeping quarters.

4.1.14 Minimal accommodation to be provided in each habitat module for degraded or emergency conditions shall include the following:

a. Sleep restraints for three people
b. contingency rations
c. full (drinking and food reconstitution) water ration
d. health care
e. working provisions (doing repair work)
f. waste management
g. personal hygiene

4.1.15 The habitability module shall accommodate experimental equipment and experiments on a space-available basis.

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5.0 LOGISTICS MODULES

5.1 GENERAL REQUIREMENTS

5.1.1 The Logistics Module shall have the capability of being berthed to any MSP berthing port available with access to the pressurized volume. The MSP design and operational guidelines will be to provide a dedicated berthing port for logistics resupply.

5.1.2 The LM shall incorporate provisions for transporting and storing the following:

• Shelf Stable Food	139 ft^3
• Frozen Food	54 ft^3
• Water	80 ft^3
• Personal Gear, Clothing, etc.	60 ft^3
• ECLS Supplies	(TBD) ft^3
• EVA Supplies	100 ft^3
• Maintenance and Housekeeping Supplies	50 ft^3
• MSP Spares	25 ft^3
• Experiment Supplies	(TBD) ft^3
• Trash Storage (Compacted)	206 ft^3

5.1.3 The Logistics Modules shall provide resupply support for three (3) crewmen for 180 days. A 30-day contingency supply shall be maintained on-board the MSP for support of three (3) crewmen.

5.1.4 The LM shall provide food for three (3) crewmen for 180 days. The food shall be stored in a controlled environment utilizing standard containers to facilitate resupply of food in food preparation area.

5.1.5 The food supply shall be stored in the HI, the HM, the Adapter/Airlock, or divided between each.

5.1.6 Transfer of all items stowed in the pressurzied volume shall be via hand-carrying.

5.1.7 Umbilical provisions shall be incorporated for transferring water and atmospheric gas into the MSP system.

5.1.8 The LM shall supply a full repressurization of the largest module volume at each resupply interval plus airlock support of two (2) crewmen per EVA for three (3) EVA's.

5.1.9 The LM shall provide storage for return of all solid waste, soiled clothing, expended personal gear and habitation gear. Provisions shall also be made for return of waste water.

5.1.10 The LM shall provide approximately 200 ft^3 of volume for stowage of processed and compacted trash. Trash should be returned in empty resupply stowage rack/canister to reduce total dedicated volume for the Logistics System.

5.1.11 In the event a crewman is isolated in an LM due to the isolation of the companion pressurized volume, a suitable rescue mode shall be provided. (EVA provisions should be considered as the rescue mode pending arrival of the Orbiter.)

5.1.12 A portable oxygen supply and a flashlight shall be provided for use in an emergency.

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6.0 SUBSYSTEM REQUIREMENTS

6.1 Structures/Mechanical

6.1.1 All major load-carrying structures of the structural subsystems shall be designed to a safe life of a minimum ten years in orbit. Life limitations shall be identified.

6.1.2 As a goal, fail-safe design concepts shall be applied to all critical structures so that failure of a single structural member shall not degrade the strength or stiffness of the structure to the extent that the crew is in immediate jeopardy.

6.1.3 The structure shall be designed to resist damage resulting from accidental impact during crew activities.

6.1.4 The design of the pressure shell and other critical structural members shall facilitate maintenance and repair. This includes the use of smooth surfaces, minimum crevices, and general accessibility.

6.1.5 Safety factors used for structural design shall be consistent with those currently used for manned operations.

6.1.6 As a design goal, atmospheric leakage of each module should be less than 0.5 lb/day with a maximum of 5 lb/day for the total MSP pressurized volume.

Strength

Ultimate - A factor of safety of 1.5 shall be applied to the ultimate strength for unpressurized structure and 2.0 for pressurized structure.

Yield - A factor of safety of 1.1 shall be applied to the yield strength for unpressurized structure and 1.5 for pressurized structure

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Fail Safe Structure

The structure shall be designed so that a credible failure mode in the structure shall result in a catastrophic failure.

Windows

Ultimate - Factor of safety greater than 3.0 (never less than 1.5 at any time during life).

Redundant - Panes

Meteoroid protection shall be provided by the MSP structural design consistent with the meteoroid flux given in NASA SP-8013.

6.1.7 Dynamic isolation is required for rotating machinery.

6.1.8 The MSP pressurized structure and subsystems shall be designed for a selectable total pressure of (TBD) psi (i.e., from 10 to 15 psi) with partial pressure O_2 at (TBD) psi.

6.1.9 Orbital operations requiring Orbiter manual docking or manual docking capability shall use the following design criteria:

Axial closing velocity	0.16 - 0.50 ft/sec
Lateral velocity	0.25 ft/sec
Angular velocity	0.6 deg/sec
Pitch, yaw, and roll misalignment	$\pm$5.0 deg roll
	$\pm$6.0 deg pitch/yaw
Radial miss distance	1.0 ft
Lateral misalignment	0.75 ft

The above data are maximum values relative to the docking interface.

6.1.10 Docking is defined as the joining in space of two spacecraft or spacecraft modules by maneuvering one into contact with the other, at the docking interface, using reaction control thrusters.

6.1.11 The MSP shall provide at least two locations for Orbiter berthing. One location shall allow nominal operations of crew transfer and logistics. The other may allow for crew transfer only.

6.1.12 Berthing is defined as the joining in space of two spacecraft or spacecraft modules by maneuvering one into contact with the other, at the berthing interface, using a manipulator.

6.1.13 Berthing-design impact conditions

Closing velocity, fps	0.05 ft/sec
Lateral velocity, fps	0.05 ft/sec
Angular velocity, deg/sec	0.1 deg/sec
Lateral misalignment, ft	0.2 ft
Angular misalignment, deg	3 deg roll
	3 deg pitch/yaw

6.1.14 The MSP/Orbiter berthing interface shall be designed to allow berthing at 90 degree alignment increments about the respective axis.

6.1.15 Berthing ports and hatches shall be sized for a nominal 40-inch diameter opening. The 40-inch diameter opening shall be "D" shaped (same as or similar to orbiter airlock and aft cabin bulkhead hatches) to allow the hatch to be passed through the opening.

6.1.16 All hatches shall be capable of operation from either side of the hatch.

6.1.17 Capability for equalization of pressure across the hatch shall be provided.

6.1.18 All hatches shall close in direction of positive pressure differential.

6.1.19 All hatches shall be provided with hinge linkages to control hatch motion.

6.1.20 Areas into which hatches open shall be designed so that the full open position of the hatch does not block crew passage.

6.1.21 All pressure hatches shall have a window.

6.1.22 All berthing ports on the Adapter/Airlock module shall be an active configuration, except Power System and Orbiter interfaces which are to be passive.

6.1.23 Any umbilical service interconnection made outside of the pressurized volume shall be automated but shall be maintainable by EVA.

5.1.24 The MSP and all associated appendage structure shall be able to withstand a (TBD) g level during attitude control and/or reboost phases of the mission.

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6.2 ELECTRICAL POWER

6.2.1 Electrical Power Generation

6.2.1.1 Electrical power may be provided by the (TBD) kw Power System using photovoltaic solar arrays and batteries. Minimum average load electrical power requirement is (TBD) kw at the load bus, averaged over a 24-hour period.

6.2.1.2 As a goal, solar cell arrays shall have a clear unobstructed view of the sun to preclude partial shadowing of their surfaces. The arrays shall be designed to provide adequate power under any partially-shadowed conditions that cannot reasonably be avoided and to preclude shadow-induced damage.

6.2.1.3 Emergency power sources shall be provided for one pressurizable volume for crew survival up to a minimum of 180 hours in LEO.

6.2.2 Electrical Power Distribution and Control

6.2.2.1 The electrical subsystem shall provide circuit protection devices for all power equipment and station distribution wiring. Redundant circuits shall be isolated. Switching to supply load busses from any source available shall be included.

6.2.2.2 Standard electrical interfaces shall be provided for power transfer between modules and other attachable elements requiring a power transfer interface with the MSP.

6.2.2.3 Emergency power buses shall be provided for time-critical MSP subsystem elements and for man-rated modules.

6.2.2.4 Critical loads shall be provided with emergency power in the event of a power system failure.

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6.2.2.5 The electrical subsystem shall provide both dc and ac service to users (mission hardware, transportation systems, etc.) as follows:

<u>DC Power</u> - 120Vdc on solar array voltage, 28 Vdc regulated, TBD voltage for battery charging

<u>AC Power</u> - - 115/200 Vac, 3-phase, 400 Hz, TBD KVA

6.2.2.6 Conversion devices shall be provided for the following:

Regulators - Convert 120 Vdc to regulated 28 Vdc nominal.

Battery Chargers - Convert 120 Vdc to TBD output

Inverters - Invert 120 Vdc or 28 Vdc to 115/200, 3-phase, 400 Hz, TBD power.

6.2.2.7 Controls shall be provided for main connect/disconnect to solar arrays, dc and ac loads, and redundancy. Controls shall limit/minimize transients and may be performed by a computer.

6.2.2.8 DC primary power grounds shall be referenced to the Power System single point ground.

6.2.2.9 Compartment gases and pressures shall not be hazardous to the electrical power system components so as to cause corrosion, deterioration, or corona. The electrical system shall be designed to be compatible with the MSP environments and outgassing products.

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6.3 Environmental Control Life Support

6.3.1 The ECLS system shall control the MSP pressurized environment to the values indicated in Table .

6.3.2 The ECLS nominal design loads are defined in Table 2.

6.3.3 Carbon dioxide partial pressure will be maintained below 7.6 mm Hg in all habitable areas. As a design goal, CO_2 partial pressure will be maintained below 3.8 mm Hg in all habitable areas. During contingency operations, CO_2 partial pressure shall not exceed 15 mm Hg.

6.3.4 The concentration of microbial count in the environment of each of the pressurized compartments containing crew quarters, process laboratories, or experimental facilities shall be monitored and controlled.

6.3.5 Contaminates resulting from experiment operations shall not adversely affect the local MSP environment.

6.3.6 Active thermal control coolant fluids in the pressurized volumes shall be water and air. Freon-21 shall be used outside the habitable volumes. Overboard gas venting is permitted. Vents shall be nonpropulsive.

6.3.7 Dumps of any matter external to the MSP shall not affect high voltage power supplies or affect the local MSP environment adversely. The design and location of vent ports shall minimize cross contamination of modules.

6.3.8 Contingency repressurization gas shall be provided to repressurize either habitat module one time or any normally pressurized module indepenent of any other module. Contingency repressurization gas shall be reuppliable as necessary by normal crew rotation and resupply operations.

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TABLE 1

ECLS PERFORMANCE REQUIREMENTS

Parameter	Units	Operational	90 Day *Degraded	Day Emergency
CO_2 Partial Pressure	mmHG			
Temperature	^oF			
**Dew Point Temperature	^oF			
Ventilation	ft/min			
Wash Water	lb/man day			
Potable Water	lb/man day			
***O_2 Partial Pressure	psia			
Total Pressure	psia			
Trace Contaminants	---			
Maximum Crew Number	per			
Maximum Crew Number	per Habitat Module			

*Degraded level is acceptable to meet a "fail operational" reliability criteria.

**In no case shall relative humidities exceed the range of 25-75%.

***In no case shall the O_2 partial pressure exceed 26.9% or be below 2.3 psia.

TABLE 2
ECLS DESIGN AVERAGE LOADS

		PEAK-VALUES
Metabolic O_2	1.84 lb/man day	3.65 lb/man day
Leakage	5.00 lb/day total	
EVA O_2	1.22 lb/8 hr EVA	3.19 lb/8 hr EVA
EVA CO_2	1.48 lb/8 hr EVA	3.87 lb/8 hr EVA
Metabolic CO_2	2.20 lb/man day	4.41 lb/man day
Drink H_2O	1.50lb/man day	
Food preparation H_2O	4.00lb/man day	
Metabolic H_2O production	0.76 lb/man day	
Hand wash H_2O	4.00 lb/man day	
Shower H_2O	8.00 lb/man day	
EVA H_2O	9.68 lb/8 hr EVA	
Perspiration and respiration H_2O	4.02 lb/man day (total	5.82 lb/man day condensate)
Urine H_2O	3.31 lb/man day	
Food solids	1.60lb/man day	
Food H_2O	1.10 lb/man day	
Urine solids	0.13 lb/man day	
Fecal solids	0.07 lb/man day	
Sweat solids	0.04 lb/man day	
EVA wastewater	2.00 lb/8 hr EVA	
Charcoal required	0.13 lb/man day	
Metabolic sensible heat	7000 BTU/man day day	14,000 BTU/man
Hygiene latent H_2O	0.96 lb/man day	
Food preparation latent H_2O	0.06 lb/man day	
Experiments latent H_2O	1.09 lb/day	
Laundry latent H_2O	0.13 lb/man day	
Wash H_2O solids	0.44%	
Shower/hand wash H_2O solids	0.12%	
Vehicle heat leak and non-ECLS thermal loads	TBD	
Air lock gas loss	2.40 lb/EVA	

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6.3.9 Module humidity level shall be maintained between 40°F and 60°F dew point temperature.

6.3.10 The ECLS system temperature control shall maintain any selected temperature, ±2°F, between the values indicated in Table 1 within the heating or cooling capacity of the system. When heating or cooling loads are high, the extreme range of temperatures shown in Table 1 are allowed.

6.3.11 Capability shall exist for dumping module(s) atmosphere overboard in the event of module contamination or fire.

6.3.12 Crew related consumable resupply shall be sized for 90 days based on the 24-hour nominal man use rate. A 30-day reserve of consumables shall be provided against the possibility that the normal resupply cycle is interrupted.

6.3.13 Provisions shall be made to prevent objectionable and noxious odors emitted in any location from being transmitted to any habitable location.

6.3.14 The atmospheric constituents, including harmful airborne trace contaminants and odors, shall be monitored and controlled in each pressurized habitable volume.

6.3.15 As a design goal, atmospheric leakage of each module should be less than 0.5 lb/day.

6.3.16 Particulate matter filtration shall be provided in the ECLS for removal of particles above 300 micron size.

6.3.17 Radiation doses which affect personnel safety must be considered from all sources, including natural environment, onboard isotope and reactor sources, if any, microwave, and solar cosmic radiation.

6.3.18 Provisions shall be made for dissipation of waste heat generated during space processing and assembly operations.

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6.4 DATA MANAGEMENT

6.4.1 The data management subsystem shall be compatible with all MSP modules, mission hardware, Orbiter, and the STDN/TDRSS communication systems.

6.4.2 System and mission status information shall be available onboard for transmission to the ground as required. This information will be available both real time and stored.

6.4.3 The data management subsystem shall provide the following functions:

a. Data recording management
b. Telemetry format selection
c. Subsystem measurements and configuration management
d. Consumables management
e. Automatic fault detection and annunciation
f. Performance evaluation and trend analysis
g. Mission hardware and detached module support
h. MSP operation planning and control support
i. Data processing management
j. Command Control
k. Central Timing

6.4.4 MSP status information shall be available as follows:

a. To the ground to confirm the existence of a safe, habitable environment and functional capabilities of critical life sustaining and operational subsystems prior to manning. Limited status information shall be available directly to the Orbiter when the Orbiter is berthed with the MSP.

b. Periodically to the ground for long-term trend analysis. logistics planning, etc.

c. Continuously to the ground during critical or emergency operations.

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d. Onboard for:
   1. Subsystem status and caution and warning display.
   2. Control of EVA/IVA activity.
   3. Control of local logistics (e.g., manipulator operations, assembly operations).
   4. Support of day-to-day operations planning.
   5. Malfunction analysis.

6.4.5 Data Recording Management

6.4.5.1 The data management subsystem shall provide control for operating temporary and permanent recorders to ensure that all desired data is recorded.

6.4.6 Telemetry Measurements and Configuration Management

6.4.6.1 The onboard computers shall provide the capability to load programmable PCM data formats and to select fixed or programmable formats.

6.4.7 Subsystem measurements and configuration management

6.4.7.1 The data management subsystem shall provide subsystem measurement data on request for CRT display. Scaling, conversion, and formatting for display presentation shall be provided, Out-of-tolerance identification shall be provided for measurements detected out of limits. The capability to determine vehicle system configuration and verification of the configuration correctness shall be provided. Status information relative to subsystem configuration and general health can be requested. Any significant deviation, along with the corrective action required, shall be displayed to the crew for further action.

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6.4.8 Consumables Management

6.4.8.1 The data management subsystem shall monitor quantity and depletion rates of consumables, compare measured quantity and depletion rates with those predicted for nominal missions, and annunciate divergent trends of consumables and display status upon crew request.

6.4.9 Automatic Fault Detection and Annunciation

6.4.9.1 The data management subsystem shall continuously monitor and assess the status of MSP subsystem performance. Detection and display of time-critical and non-time critical failures shall be presented to the crew via CRT display and/or annunicator panels. Fault detection and isolation shall be provided through the use of limit checks (variable and fixed), reasonableness calculations, BITE monitoring, correlation checks, voting results, and other techniques as applicable. Visual indicators shall be activated when subsystem faults are time critical for subsystem restoration. Provisions shall be made for both CRT and hard copy printout of maintenance/repair instructions to correct faults.

6.4.10 Performance evaluation and trend analysis

6.4.10.1 The capability for performing mathematical calculations on inflight measurements in the MSP and experiment modules to predict performance at specified points within the systems shall be provided. The data management subsystem shall also be capable of making performance measurements at these specified points for a comparison of theoretical and actual performance. The results of these calculations shall be used to establish trend performance for long-term station systems performance evaluation.

6.4.10.2 These evaluations shall encompass potential mechanical and electrical system failures, gradual drifts toward out-of-tolerance conditions, and mission profile or crew procedure changes. The points at which calculations are made shall be selected to maximize the usefulness of the data management subsystem in providing long-term trend analysis.

6.4.11 Mission Hardware and Detached Module Support

6.4.11.1 The data management subsystem shall provide the capability to monitor experiment subsystem health status as well as that of detached unamanned/manned modules. The MSP data management subsystem shall be capable of interacting with similar systems onboard the detached mdoules. The interface between these systems shall be a PCM data stream obtained from hardlines or RF communication links. Accommodation of variable data rates and formats to the extent that these may be changed, for each experiment shall be provided.

6.4.11.2 The data management subsystem shall have the capability to transmit commands to all the MSP subsystems and mission hardware and receive command confirmation.

6.4.11.3 The MSP shall have the capability to receive, store, and transfer commands from the ground or Orbiter to detached modules and/or mission hardware.

6.4.12 Data for MSP orbit determination and short range ephemeris predictions shall be provided.

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6.5 COMMUNICATIONS AND TRACKING

6.5.1 The communications and tracking subsystem shall be designed to provide communications and tracking services to the ground station via relay satellites, the Orbiter, EVA, GPS, OTV, free-flyers, other cooperating vehicles, remote teleoperators, and co-orbiting satellites that will be serviced by the

6.5.2 The communications and tracking subsystems shall provide the capability for the following:

a. Reception, transmission, processing, and distribution of multiple duplex voice channels.
b. Generation, processing, distribution, transmission, and reception of television signals.
c. Transmission of operational telemetry and wideband experiment data.
d. Reception and processing of wideband digital data and commands.
e. Reception and processing of uplink text and graphic material independent of crew participation.
f. Transmission of commands to experiments and/or detached modules as required.
g. Reception of experiments and/or detached module as required.
h. Transmission and reception of EVA data.
i. Tracking cooperative and passive targets.
j. Ranging between the STDN, via TDRSS, and the MSP. This includes a one-way and two-way Doppler tracking capability.

6.5.3 The normal uplink and downlink channels shall operate between the STDN and the MSP at S-band and Ku-band frequencies through the TDRSS. The communication links between the MSP and the Orbiter shall operate at S-band frequencies; the links between the MSP and the detached modules shall be at S-band.

6.5.4 The capability for voice conference shall be provided between the Orbiter, the ground network and the MSP, and between MSP and ground network during periods of EVA activity. The audio subsystem shall provide the capability to process, amplify, mix, switch, and distribute voice to and from multiple user locations, hardline interfaces, and radio frequency interfaces.

6.5.5 For each manned state of platform buildup and operations, MSP-ground and MSP-Orbiter duplex voice communication capability shall be available from any pressurized volume the crew might retreat to when an emergency condition exists.

6.5.6 Internal communications shall be available in all habitable areas of the MSP and all active berthing ports. Internal communications shall not be interrupted nor degraded within the remaining pressurized volume due to a malfunction of a single or a group of MSP modules.

6.5.7 Generation, processing, distribution, transmission, recording and reception of television, text and graphics signals shall be provided. Closed circuit TV shall be available for crew entertainment, support of docking, and/or special area monitoring. Ground commanded and crew initiated hard copy readout shall be provided.

6.5.8 Manned Space Platform attitude constraints should not be required to maintain acceptable circuit performance.

6.5.9 A capability for RF and hardline communications with EVA crewmen will be provided.

6.5.10 The assembled modules shall provide multiple duplex voice, caution and warning signals, and video links throughout the mission.

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6.5.11 System and mission status will not necessarily be transmitted to the ground on a real-time basis, but real-time capability will exist.

6.5.12 The MSP shall provide a communication link through the berthing interface systems with the communications system of attached vehicles.

6.5.13 All equipment will be capable of being maintained in a quiescent or powered-down configuration and reactivated by command channels from the MSP or ground.

6.5.14 The communications and tracking system shall interface with the integrated entry and display system via a communications and tracking monitor and configuration management subsystem. The communications and tracking monitor and configuration management subsystem shall provide status monitoring, automatic configuration management, fault isolation, and all necessary display/control functions for operations.

6.5.15 The overall communications and tracking reliability requirements will be met through long-life design, scheduled maintenance and repair, and redundancy.

6.5.16 Generation, processing and telemetry transmission of subsystem operational data shall be provided by the Communications and Tracking System.

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6.6 FLIGHT CONTROL

6.6.1 The Manned Space Platform shall maintain a continuous orbital position fix through an onboard ephemeris program using perdiodic updates.

6.6.2 There shall be onboard tracking and orbital ephemeris generation capability for detached modules under MSP control.

6.6.3 The MSP control system shall provide three-axis control torques to counter external and internal disturbances, maintain stabilization of the various flight modes, and effect attitude maneuvers for reorientation of the MSP and/or control system desaturation.

6.6.4 The Manned Space Platform must be stabilized for initial manning and buildup.

6.6.5 Stabilization and control will be provided by the Power System during assembly of large structures.

6.6.6 Pointing and stability requirements for mission hardware (scientific experiments) which are in excess of those required for normal operations shall be provided by (TBD).

6.6.7 The capability of maintaining dynamic stability when moving large masses relative to one another is required.

6.6.8 The nominal flight orientation will be a flight mode to minimize the accumulation of momentum from aerodynamic and gravity gradient torques.

6.6.9 The Power System shall be capable of stabilizing the configuration to ± 0.3 degrees and 0.005 deg/sec for berthing.

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6.7 CREW SUPPORT

6.7.1 The MSP shall be capable of operating in both single and multiple shift modes.

6.7.2 Crew transfer from the Orbiter to the MSP shall be performed in a shirtsleeve environment.

6.7.3 Routine evaluation of crew health shall be performed onboard. Medical care will be provided by trained crewmen (at least to paramedic level).

6.7.4 The MSP shall accommodate a mixed male-female crew.

6.7.5 Crew systems shall be designed using the 5th and 95th percentile male and female NASA astronaut anthroprometrics adjusted for 30 year growth trends.

6.7.6 The initial MSP shall be sized to accommodate at least three crewmen.

6.7.7 Provisions for double occupancy will be made for exchange crew overlap periods. The maximum crew size will be ten (10) crewmen for seven (7) days. (3 MSP crewmen and 3 replacement MSP crewmen and 4 Orbiter crewmen.)

6.7.8 During MSP operation a minimum of two separate pressurized habitable volume with independent life support capability and habitability provisions for a nominal crew for 90 days will be provided.

6.7.9 Lighting

a. Control Panels and Task Areas: 538-1076 lx (50-100 ftc) adjustable-selectable (with auxiliary 200 ftc spotlite, if required). Suitable for inspection of small details, and small delicate operations.

b. Habitat Areas: 215-538 lx (20-50 ftc) adjustable - selectable. Suitable forreading and general office work.

c. General Areas: 108-205 lx (10-20 ftc). Suitable for normal activities such as galley, washroom, passageways and storerooms.

d. Contingency: 22-54 lx (2-5 ftc). The MSP shall have an emergency lighting system in all passageways and compartments.

e. Portable Lighting: Portable flashlights and lanterns shall be strategically stored in specific locations for use during maintenance, repair, and emergencies.

6.7.10 Crew Accessories

6.7.10.1 Entertainment equipment shall be included that will provide mental stimulation different from normal mission tasks.

6.7.10.2 The equipment shall include but not be limited to, audio devices, game devices, and reading devices.

6.7.10.3 Means shall be provided to ensure both visual and acoustical privacy for a crewman during his off-duty periods.

6.7.11 Each crewman shall have individual personal items storage provisions located in each crewman's privacy area.

6.8 EXTRAVEHICULAR ACTIVITIES (EVA)

6.8.1 The maximum EVA duration shall be as follows:

a. Maximum of six hours/crewman/24-hour day - for crewmen performing routine EVA six days/week on extended orbital tours.

b. Maximum of eight hours/crewman/24-hour day - for crewmen performing infrequent EVA.

C. Maximum continuous EVA - three hours (for routine EVA only).

6.8.2 Airlock design and/or operational procedures will permit reentry of EVA crewman for two-hour break between EVA sojourns without the necessity for prebreathing prior to resuming EVA.

6.8.3 EVA consumable makeup resupply capability shall be based on 24 six-hour EVA's per week as a minimum. Backpack recharge O_2 shall be supplied by (TBD).

6.8.4 No "pre-breathe" shall be required before EVA. EVA suit pressure will be 5.75 psia pure oxygen.

6.8.5 The capability for a variable controlled rate of depressurization and repressurization of the EVA airlocks is required. The nominal rate is not to exceed 0.1 psi/sec. The emergency rapid depressurization is not to exceed 1 psi/sec. Depressurization control should be possible from inside and outside the MSP as well as from inside the airlock. Repressurization control shall be possible from both inside the MSP and inside the airlock. Life support umbilical connectors shall be available outside the airlock.

6.8.6 Provisions for EVA preparation, EVA equipment storage, recharge, checkout, maintenance and post-EVA activities shall be made in an adjacent pressurized compartment.

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6.8.7 All IVA hatches shall be capable of operation from either side of the hatch, and a capability for equalization of pressure across the hatch shall be provided. Translation means will include handrails/handholds and by MMU. Handholds, handrails, and restraint attach points must be provided along all EVA/IVA routes and at each EVA hatch.

6.8.8 Opening of hatches used for EVA must be possible from both inside and outside the MSP. Hatches shall close in direction of positive pressure differential resulting from normal operations (e.g., interior entry hatch to EVA module) or emergency procedures (e.g., exit hatch from berthed EVA module).

6.8.9 Each pressure hatch that is capable of being closed during either normal or emergency operations shall have a window.

6.8.10 Airlocks for routine EVA shall be designed as not to preclude pumpdown capability to 0.2 psia.

6.8.11 EVA shall consider use of:

- Saws, Files, Shears
- Miter Box
- Debris Control
- Drills, Reamers, Hole Saws, Punches
- Clamps, Wrenches, Riveting Tools, Pin Expansion Tool
- Welders--Electron Beam, Spot, Seam
- Fusing, Reduction Heating Coil
- Snap Lines, Measuring Rods
- Optical Surveying Systems (Rangefinder, Transit)
- Gages, Measuring Tapes
- VOM, Discontinuity Meters
- Valve Actuation Handles
- Leak Detection Gear
- Cleaning Wipes

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6.8.12 Generous use of locomotion and restraint devices will be provided in external design to accommodate unanticipated EVA requirements. Portable EVA work restraints will be provided for seldom used work locations and for unanticipated EVA requirements.

6.8.13 Continuous voice contact will be provided between EVA crewmen and between EVA crewmen and the control center.

6.8.14 EVA hardware and crew procedures shall be designed to minimize metabolic output. EVA tasks shall not require more than the 1,265,220 joules (1200 BTU/hr) to perform.

6.8.15 As a design goal, tasks that require fine alignment of hardware components should utilize alignment/insertion guides.

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7.0 FLIGHT SUPPORT REQUIREMENTS

7.1 ORBITAL ASSEMBLY FACILITIES

7.1.1 The MSP assembly facility shall be capable of assembling large space systems, including subsystem installation and system check-out, and launching them to their operational orbits.

7.1.2 Configuration

a. Structures - The facility shall be capable of assembling various shaped platform structures up to TBD wide and TBD long with a maximum mass, including subsystems, of TBD kg.
b. Antenna - The facility shall be capable of assembling parabolical antenna structures up to (TBD) m in diameter, with a maximum mass, including subsystems of (TBD) kg.

7.1.3 The facility shall be capable of maintaining the alignment of the assembled structure within (TBD) cm.

7.1.4 The facility shall be capable of installing on the structures all subsystems required for complete, operational space systems. These subsystems shall include, but not be limited to, electrical power, thermal control and heat rejection, propulsion and attitude control, guidance and stabilization, communications, data management, mechanical systems, and specialized subsystems peculiar to a specific space system or mission.

7.1.5 The facility shall be capable of calibrating installed subsystems as required. It shall be capable of checking out the operation of the completed system prior to release from the MSP.

7.1.6 The MSP shall be capable of releasing the assembled space system and initiating the launch of the system to its operational orbit.

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7.1.7 In addition to specifically assembly-related functions, the MSP shall provide the following non-unique support:

Electrical Power:	TBD kW continuous
	TBD kW peak
Illumination:	TBD Lumens/m^2 over
	TBD area
Stabilization:	TBD deg/sec
	TBD deg/sec^2
EVA:	TBD per week
Data Management:	TBD bps
Information Storage:	TBD bits
Material Storage:	TBD m^3

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7.2 SPACE VEHICLE SUPPORT REQUIREMENTS

7.2.1 The MSP shall provide berthing capability for TBD elements of space vehicles awaiting assembly at any given time.

7.2.2 The MSP shall provide access to all berthed elements of a space vehicle for inspection, maintenance, and servicing activities. Consideration shall be given for providing a range of thermal control from a sunscreen up to a pressurized hangar.

7.2.3 The MSP shall provide continuous unobstructed IVA access to the crew cabin of an MOTV while docked.

7.2.4 The MSP shall have the capability to assemble all elements of a space vehicle from their individual berthed positions to the final launch configuration.

7.2.5 The MSP shall provide the capability of transferring propellants from the Shuttle Orbiter to the stage(s) of an OTV.

7.2.6 The MSP shall provide necessary maintenance, monitor, and check-out equipment for interfacing with the manned OTV onboard check-out system for verifying OTV systems status. The capability to telemeter data to the ground via the MSP shall be provided.

7.2.7 The MSP shall provide the capability to perform final verification and checkout of space vehicle payloads. Specialized payload related checkout equipment shall be provided by the payload. Standard power, mounting, and similar provisions to be provided by the MSP.

7.2.8 The MSP shall be capable of controlling the launch of manned OTVs via communications with ground-based control, autonomously with MSP-based control, or in support of OTV crew control. For unmanned OTVs, launch control shall be via communications with ground-based control or MSP-based control.

7.2.9 Standoff distances for the operation of OTV main propulsion and RCS shall be commensurate with those for the STS.

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7.3 ASSEMBLY AND GENERAL PURPOSE SUPPORT EQUIPMENT REQUIREMENTS

7.3.1 Assembly activities should be isolated from crew habitability to reduce noise and other disturbances.

7.3.2 Collision avoidance software and/or maximum torque override shall be incorporated in manipulators and other supporting equipment.

7.3.3 MSP design should provide direct visibility for a large portion of the assembly zone, particularly in the high activity areas where assembly and EVA is being performed.

7.3.4 When positioning and assembly operations are to be performed using EVA, a work station and aids shall be available to assist in final positioning of parts/subassemblies.

7.3.5 Voice communications and visual surveillance of EVA crew shall be provided.

7.3.6 The MSP shall provide a complement of general purpose support equipment. A preliminary list is provided in Table 3.

TABLE 3

General Purpose Support Equipment

- Lighting
  - Fixed-Flood Lights, Spot Lights
  - Portable-Flood Lights, Spot Lights
- Photographic Cameras-Still and Movies
- Closed Circuit Television-Fixed and Handheld Cameras
- EVA Systems
- EVA Suits
- EVA Tools
- Portable EVA Work Station
- Manipulator Accessories
  - Small Object Handling Tool
  - Large Object Handling Tool
  - Turntable/Tilttable
  - Umbilical System

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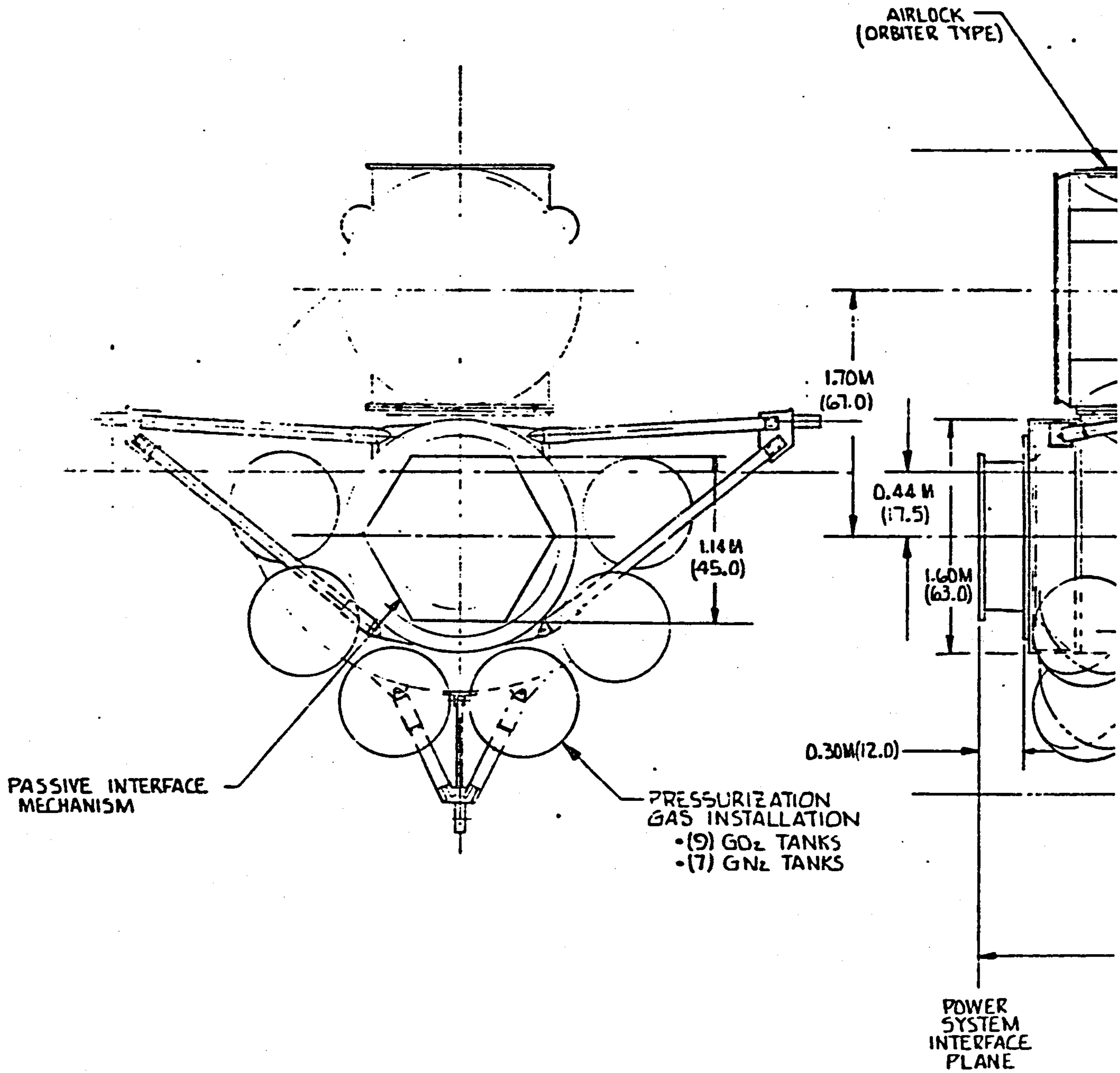

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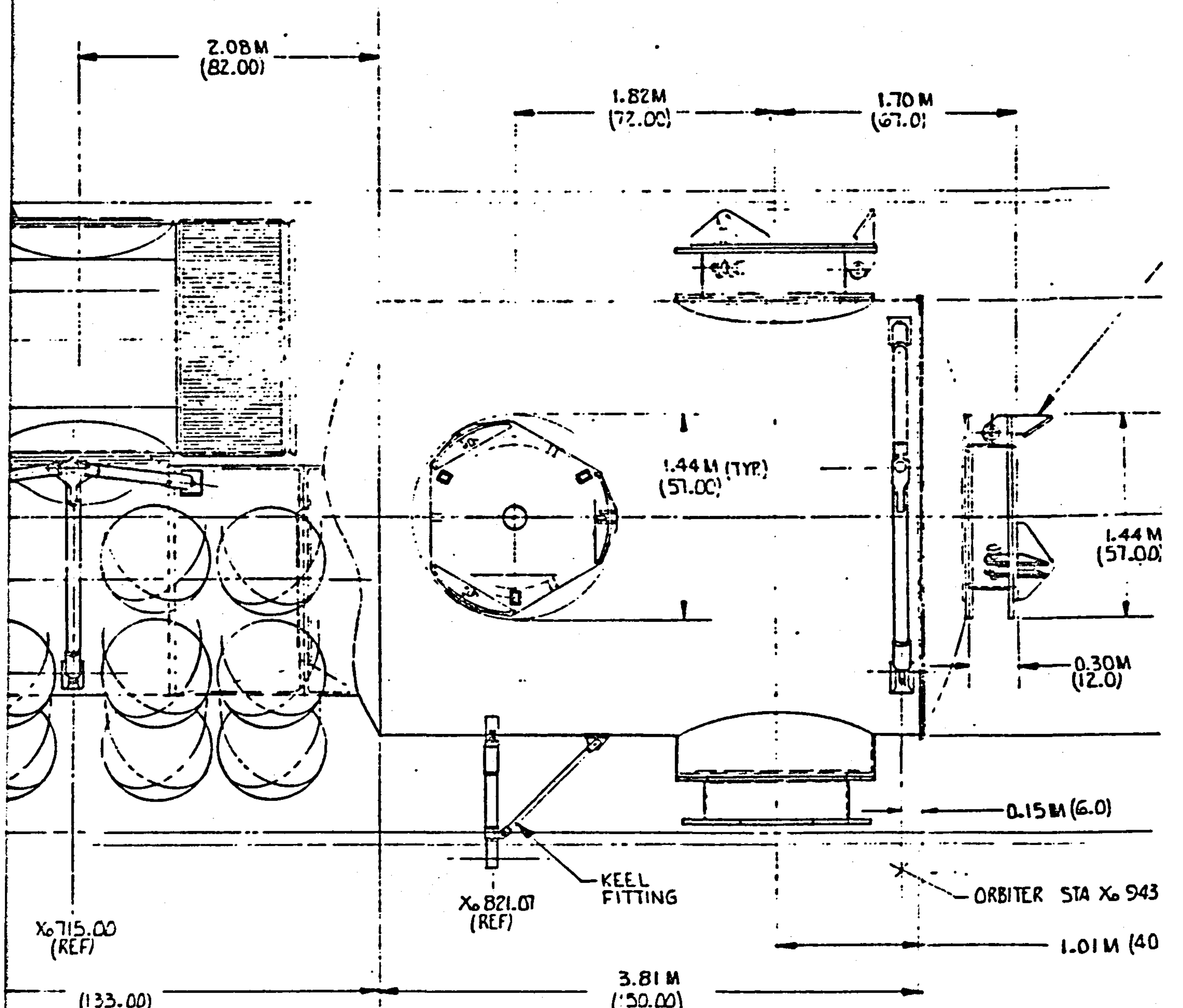

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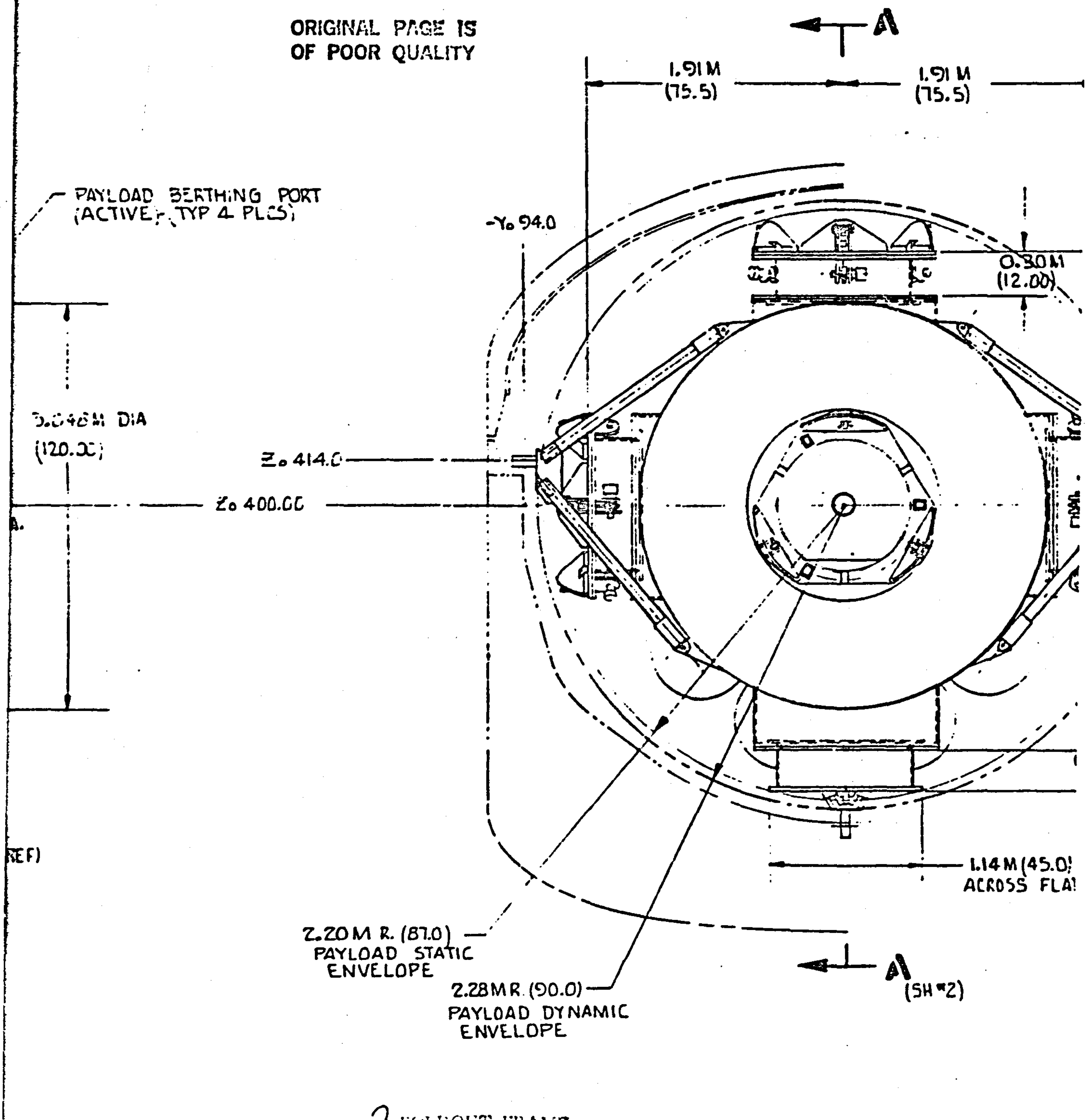

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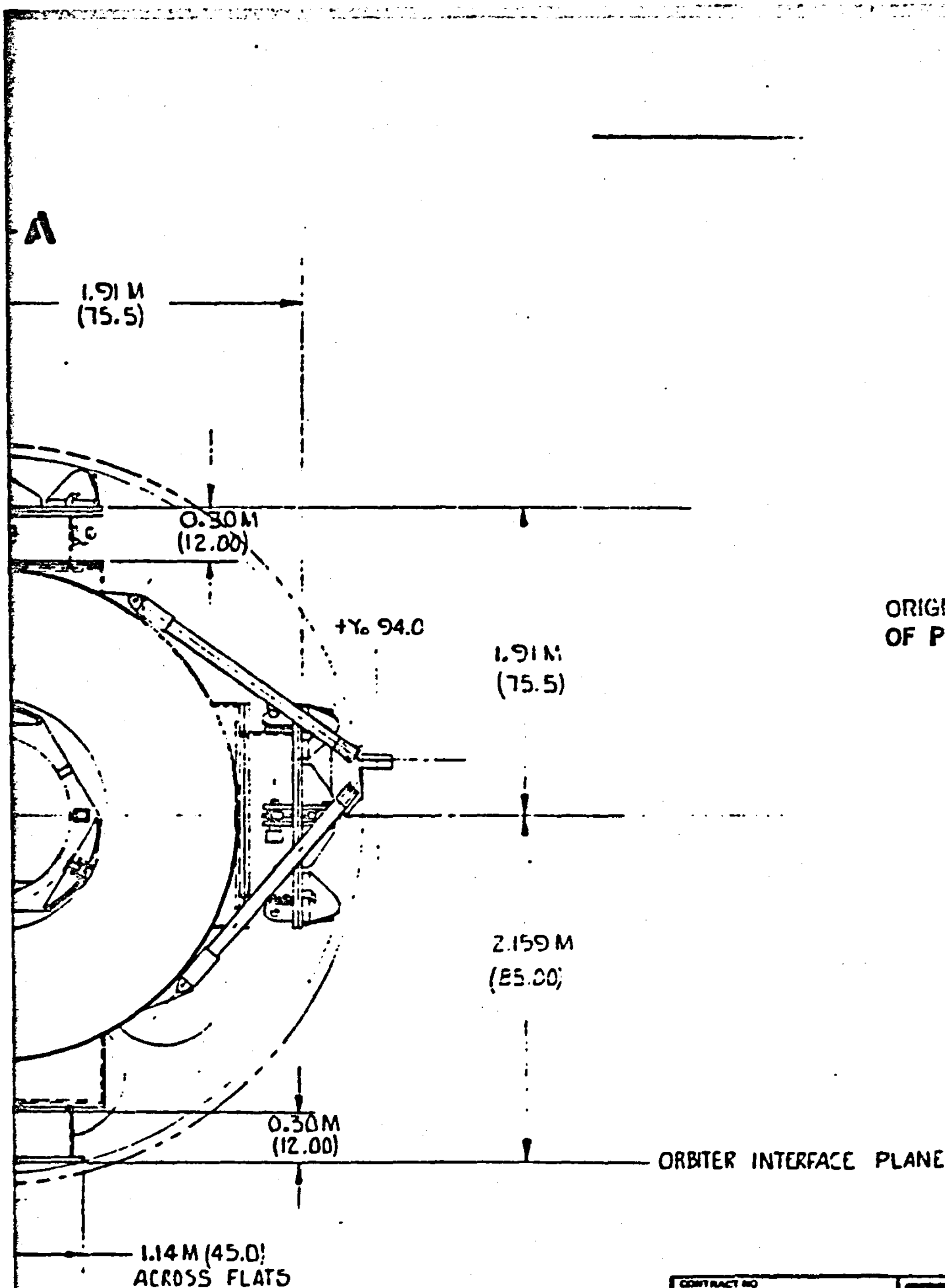

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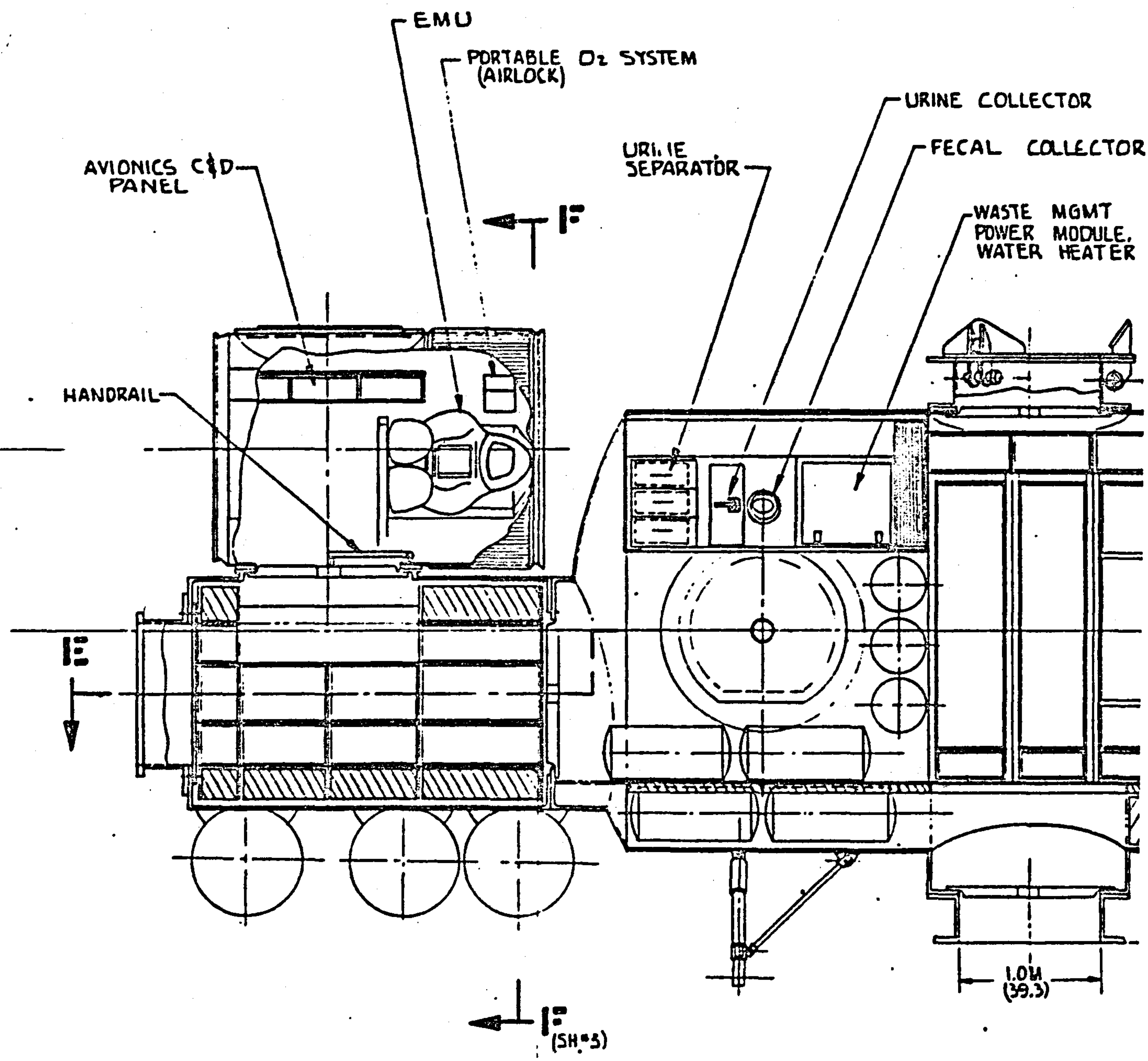

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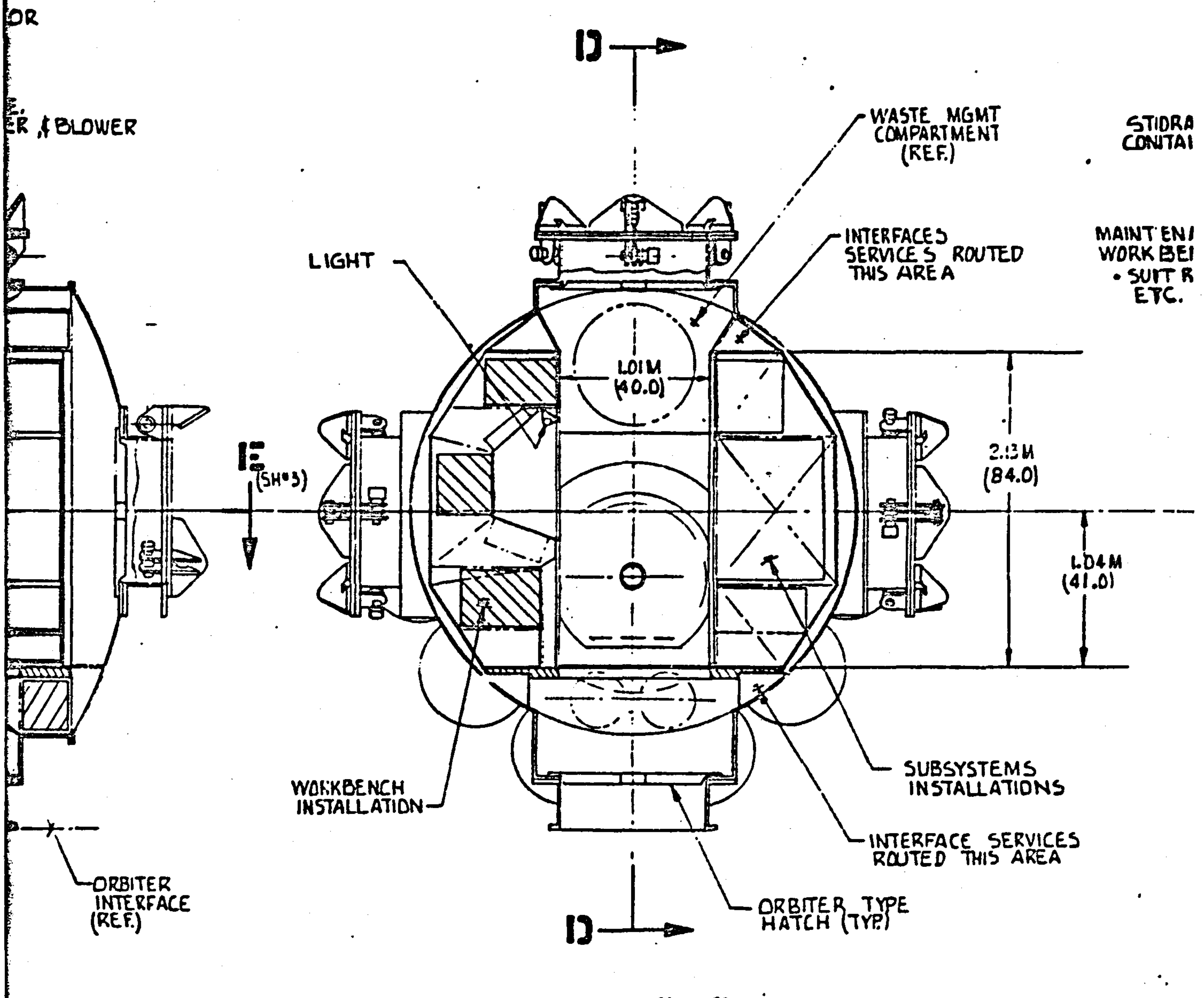

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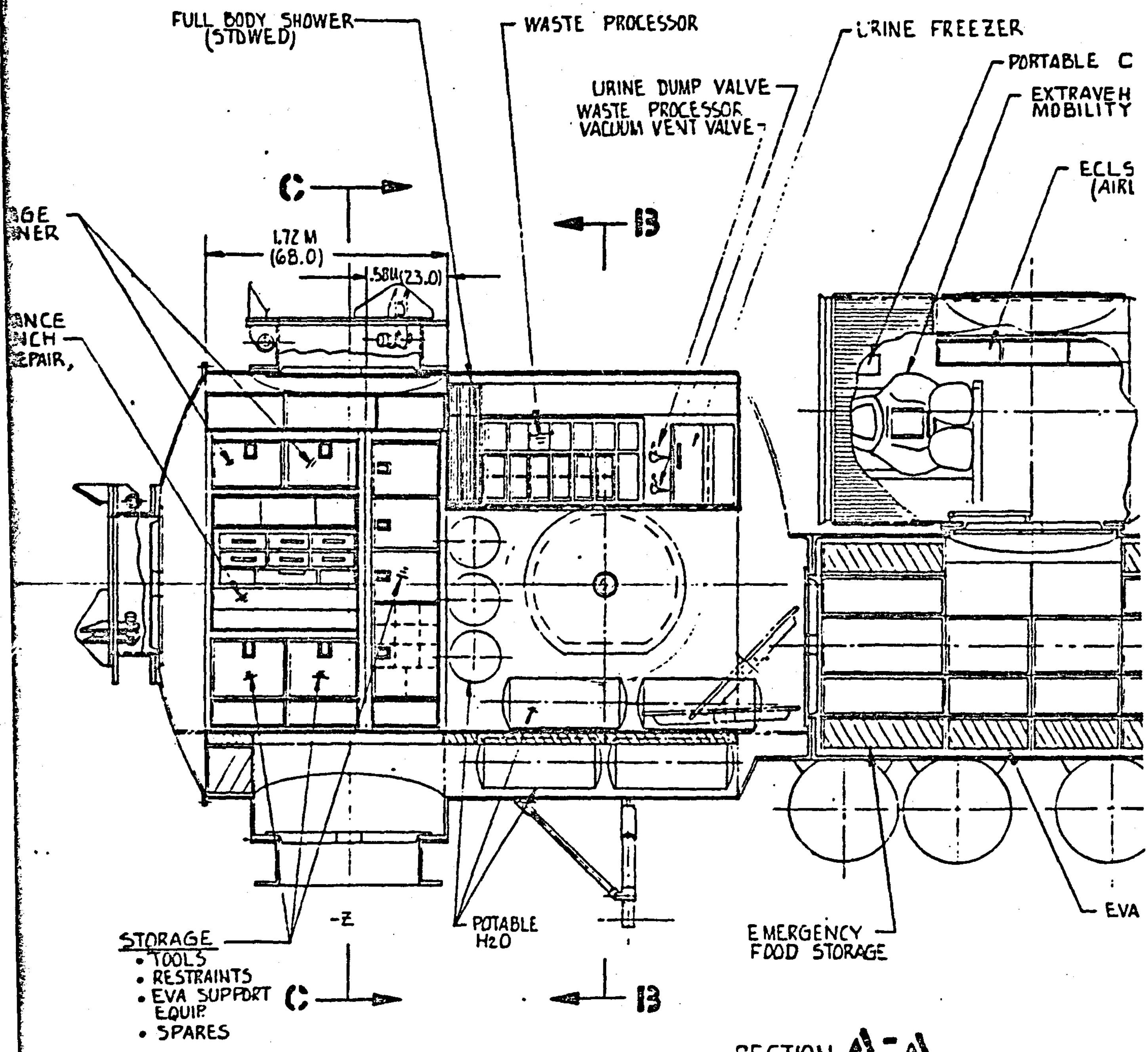

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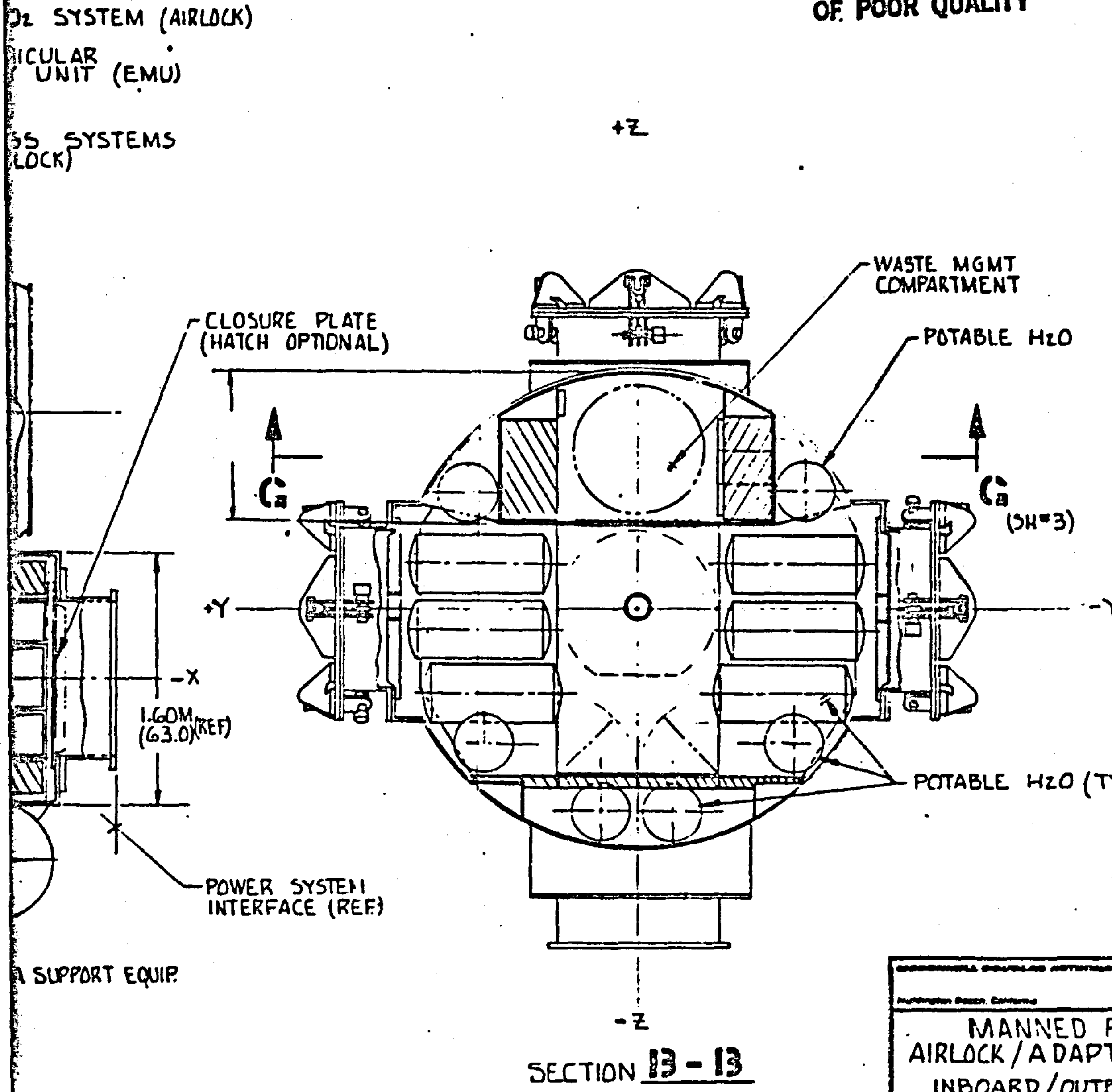

SECTION 13 - 13

MANNED PLATFORM -
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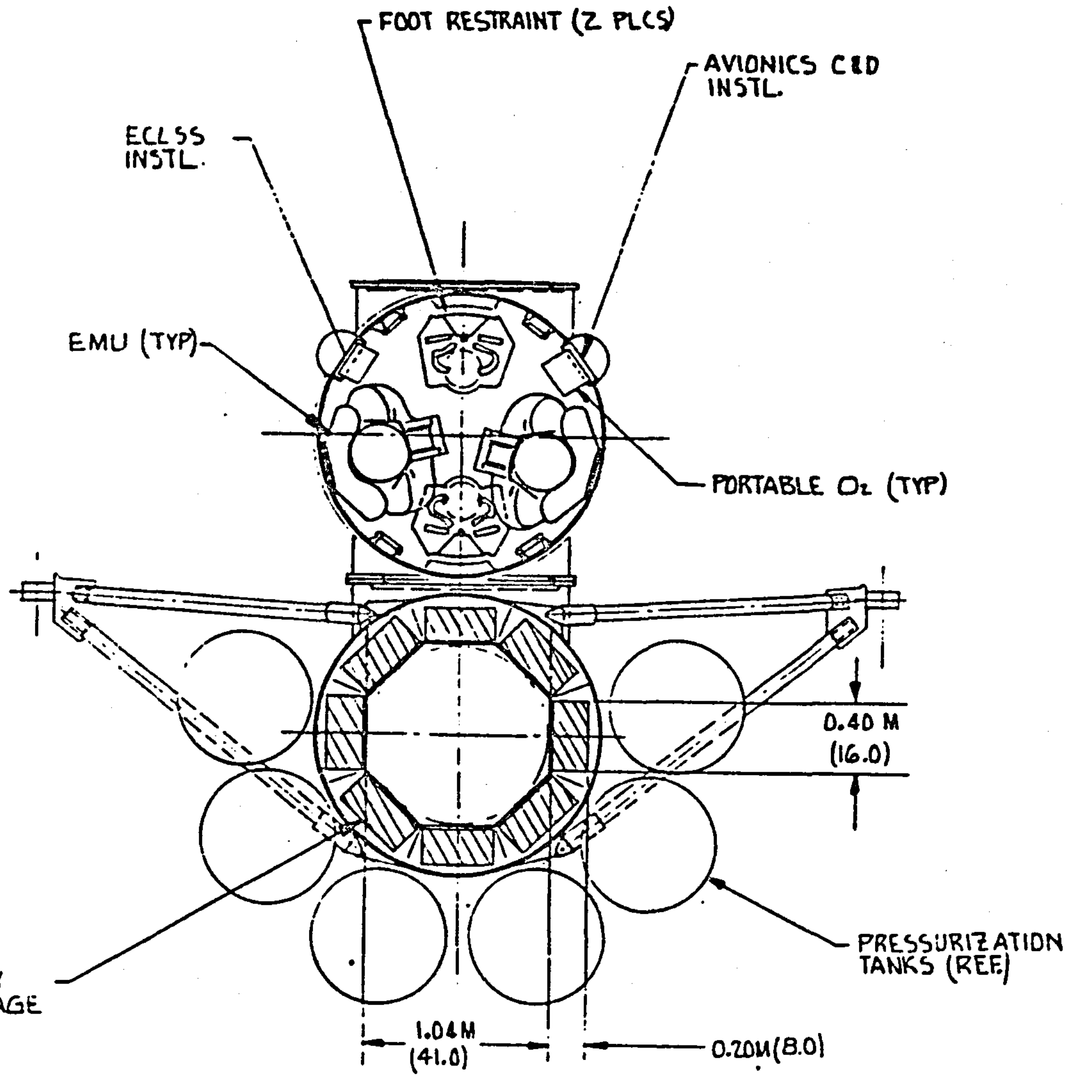

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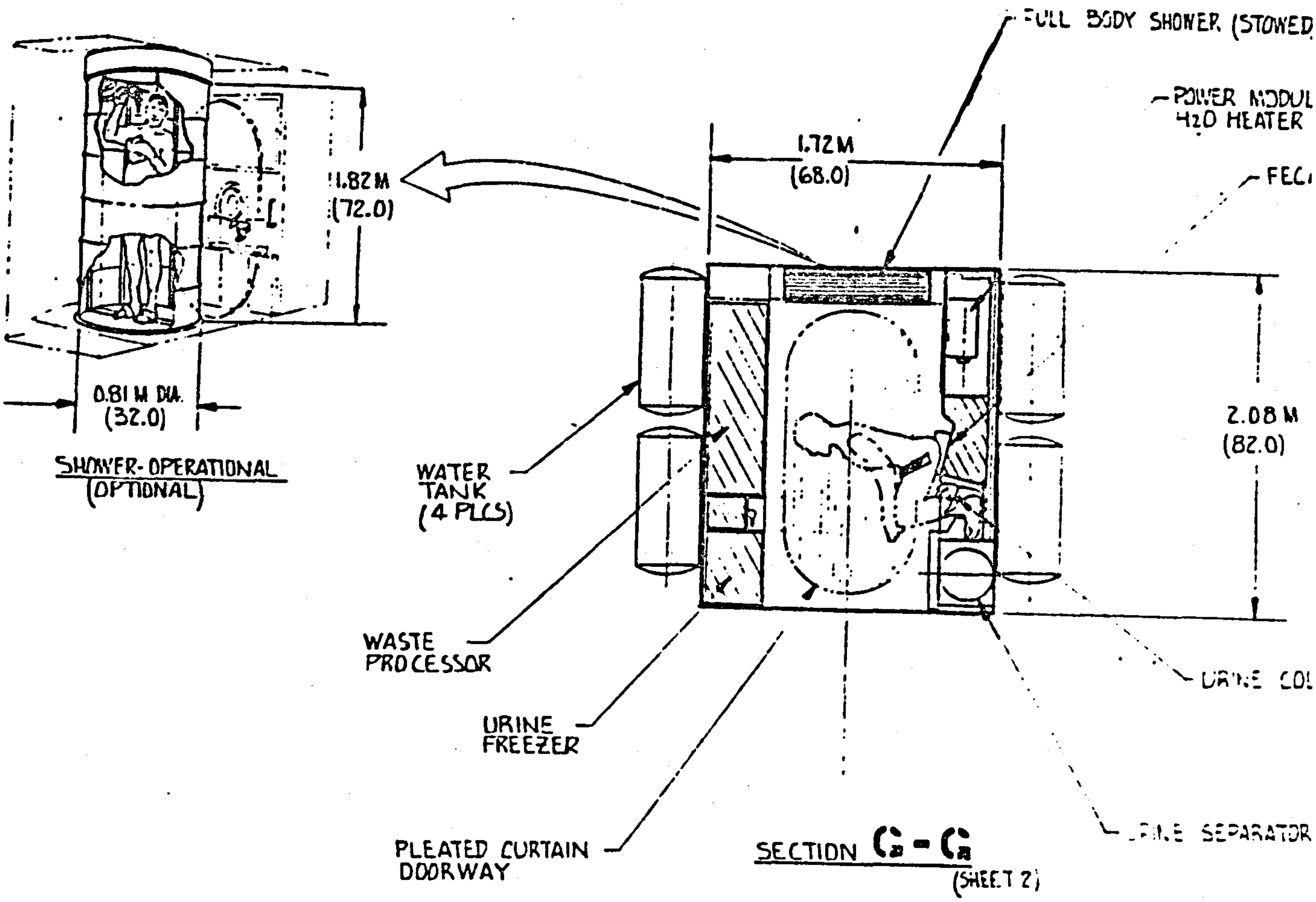

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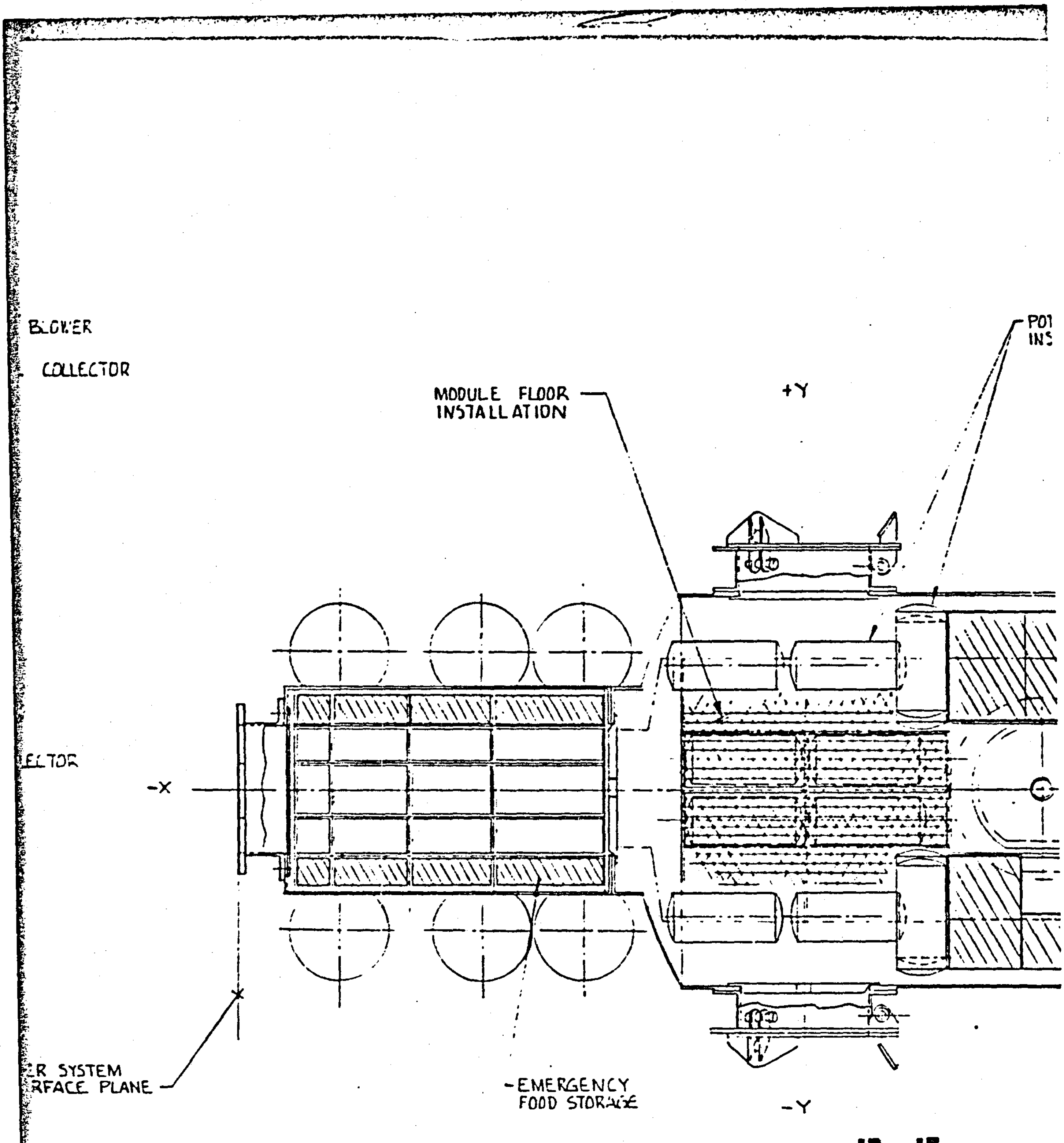

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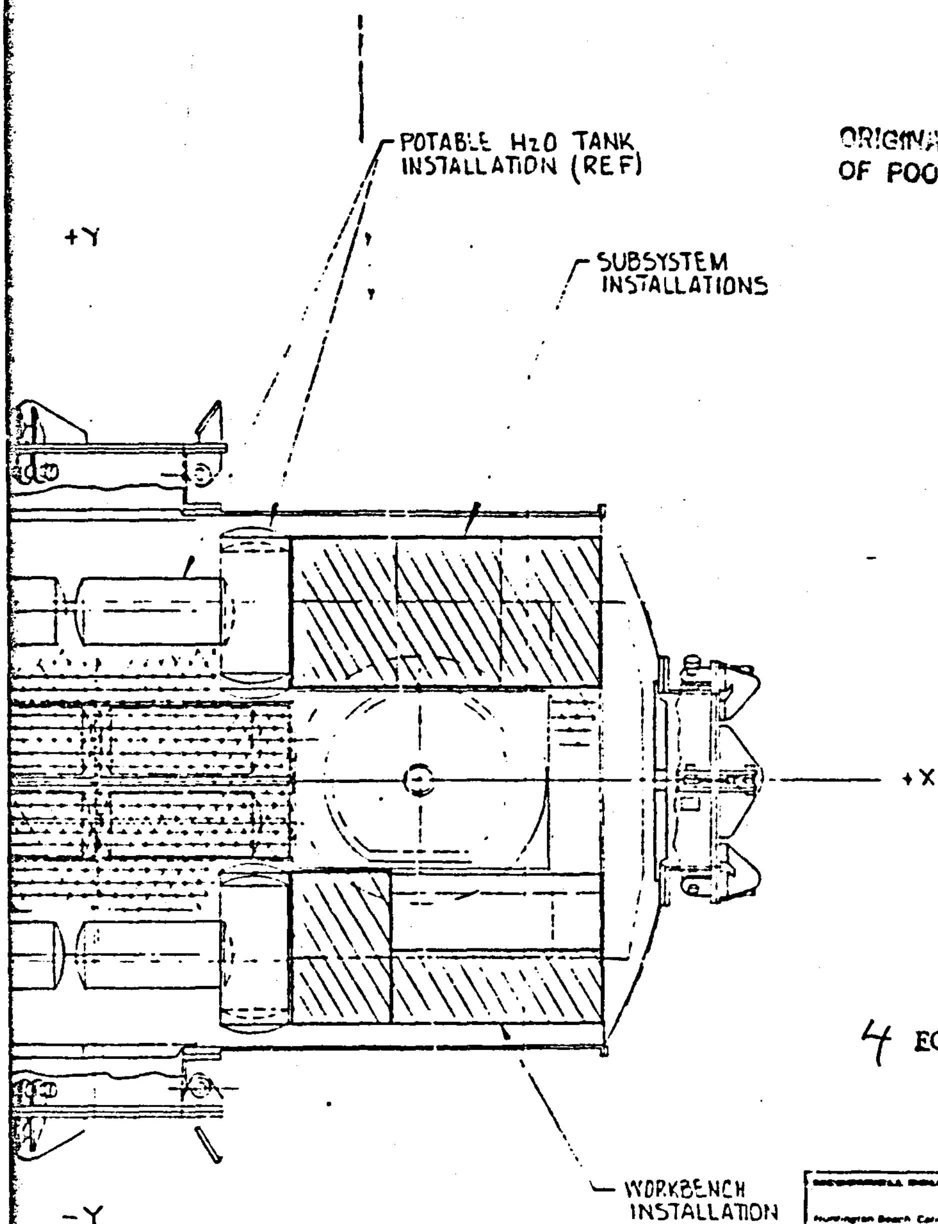

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AIRLOCK/ADAPTER MODULE-
INBOARD/OUTBOARD PROFILE

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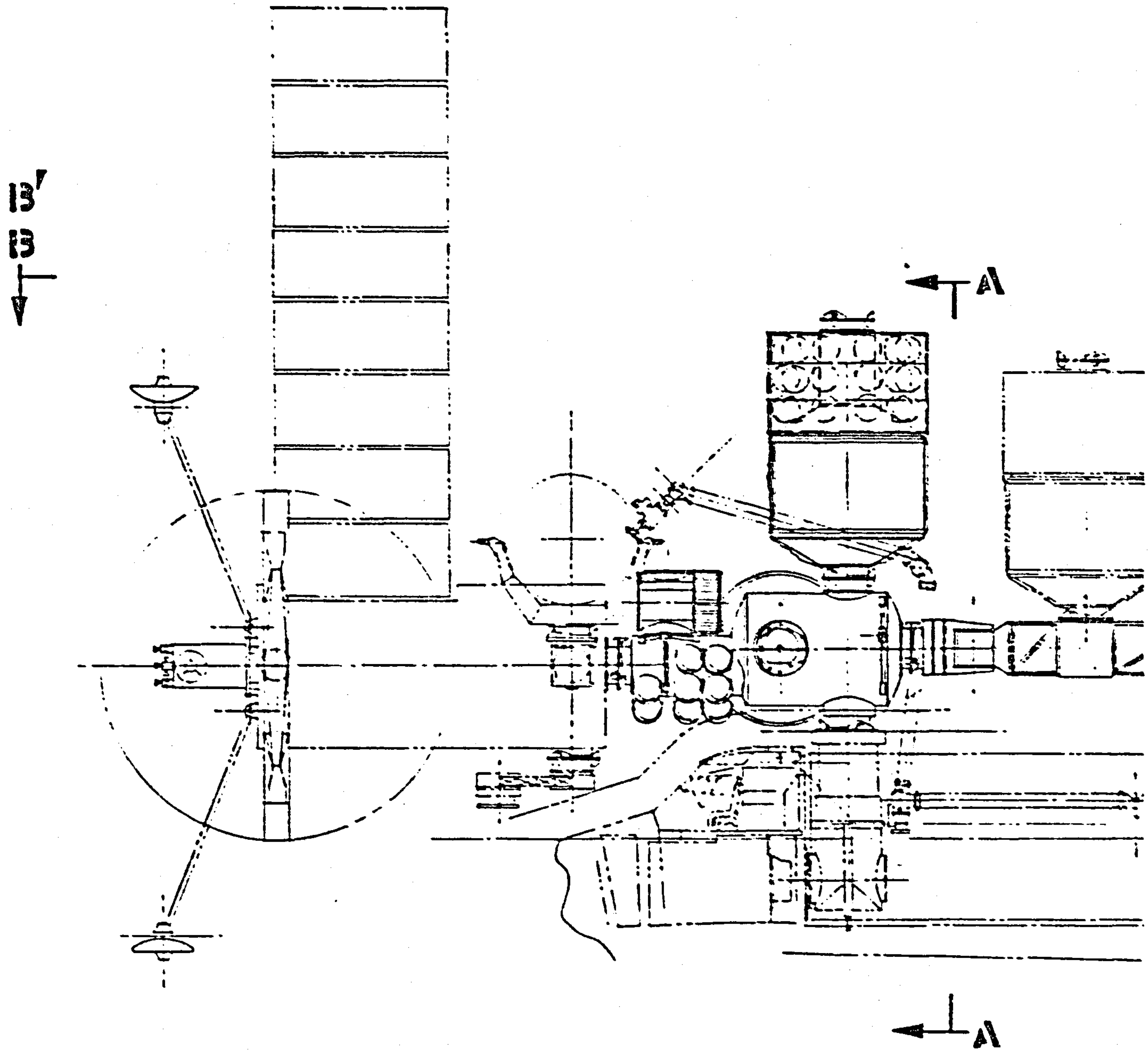

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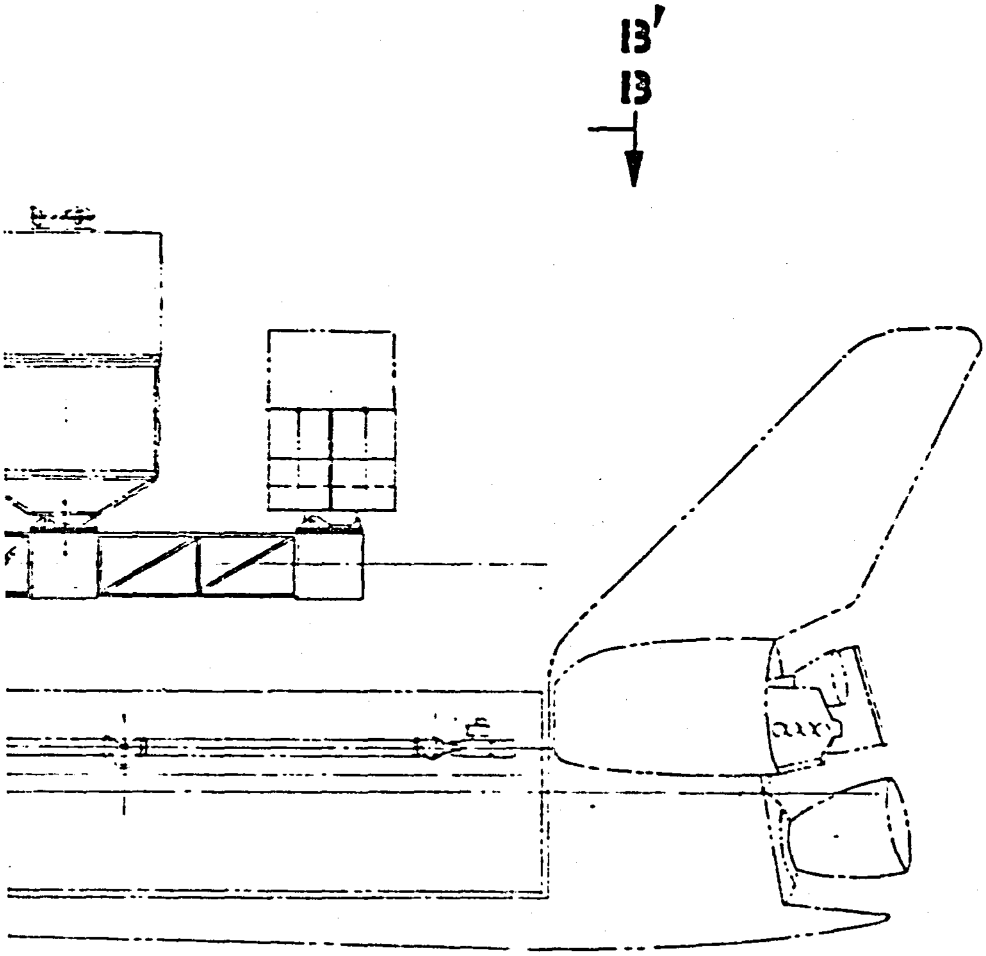

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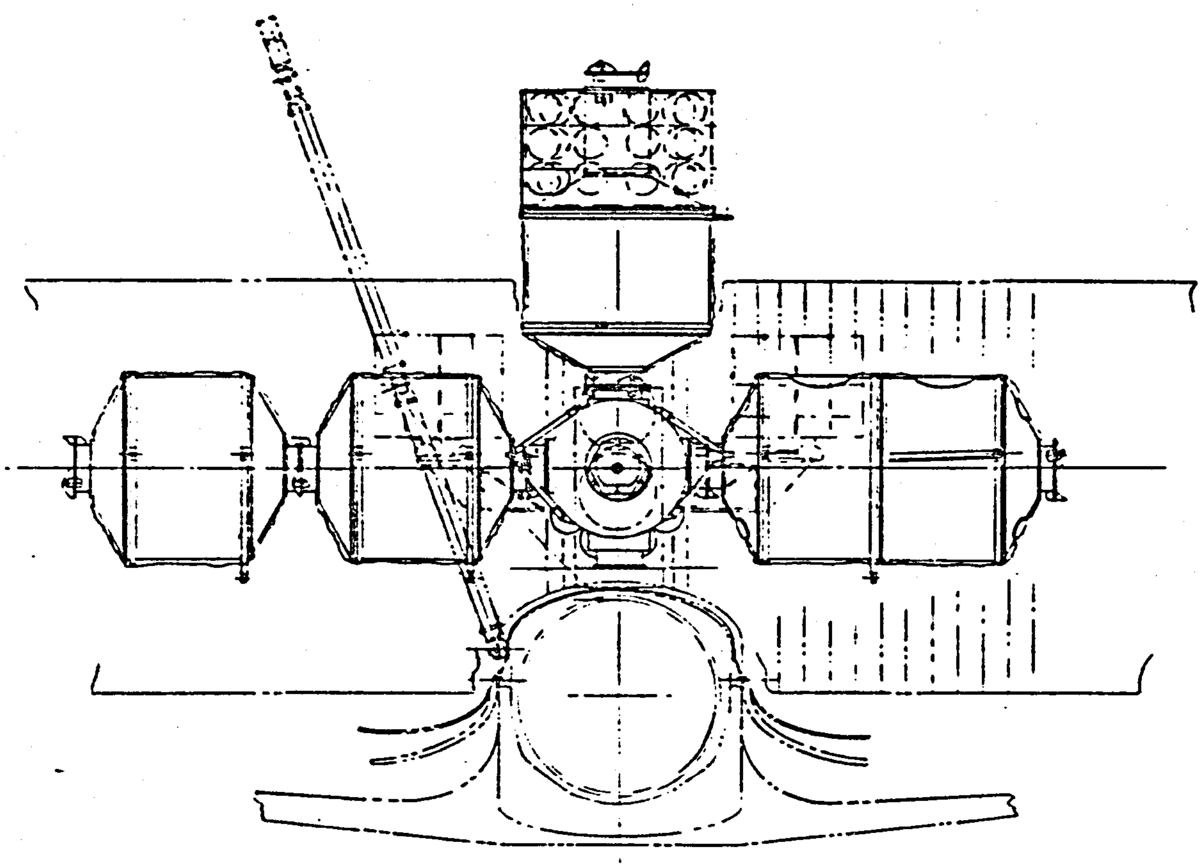

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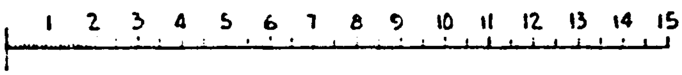

FIGURE 4.3.2.2-2/1

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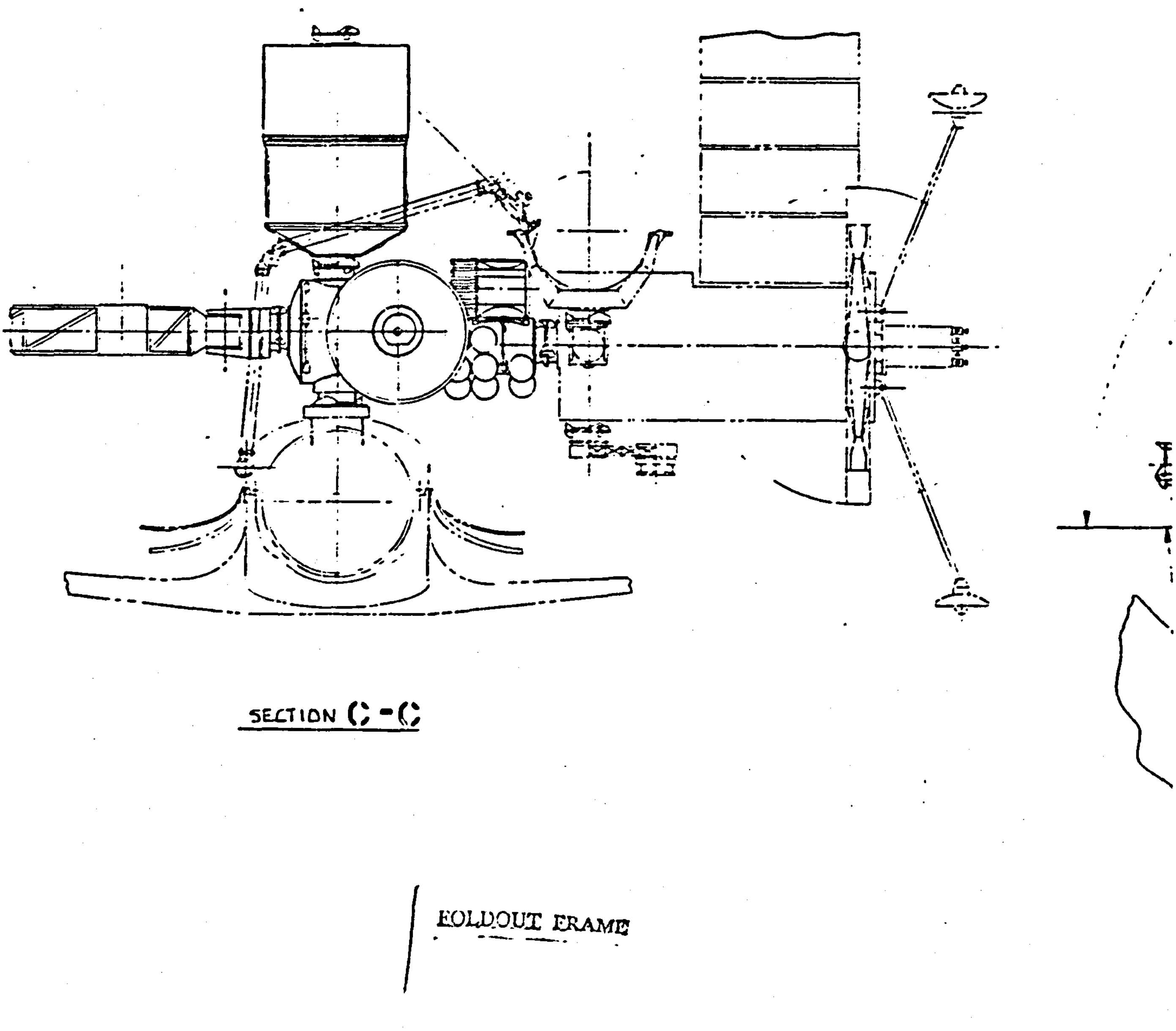

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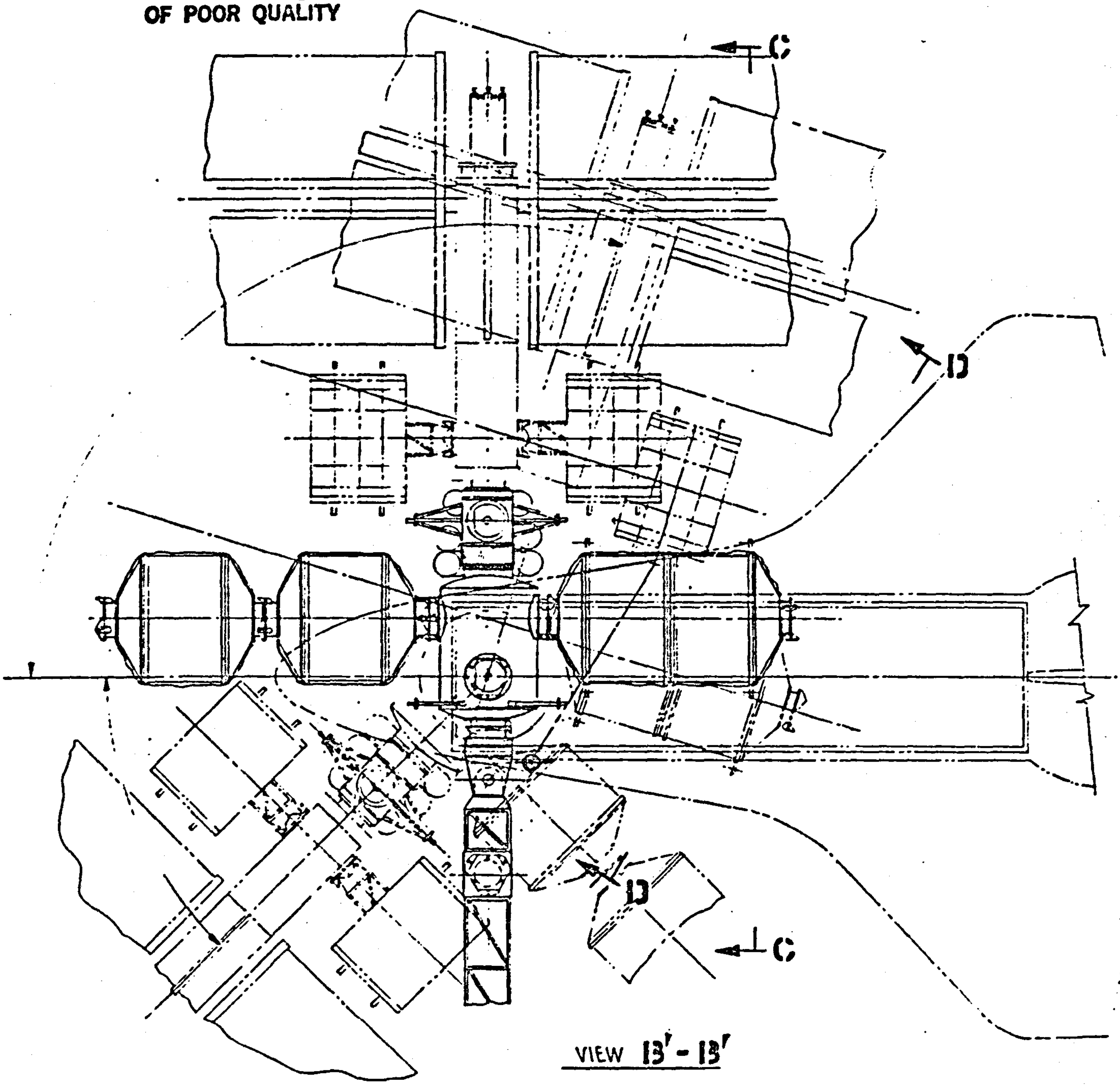

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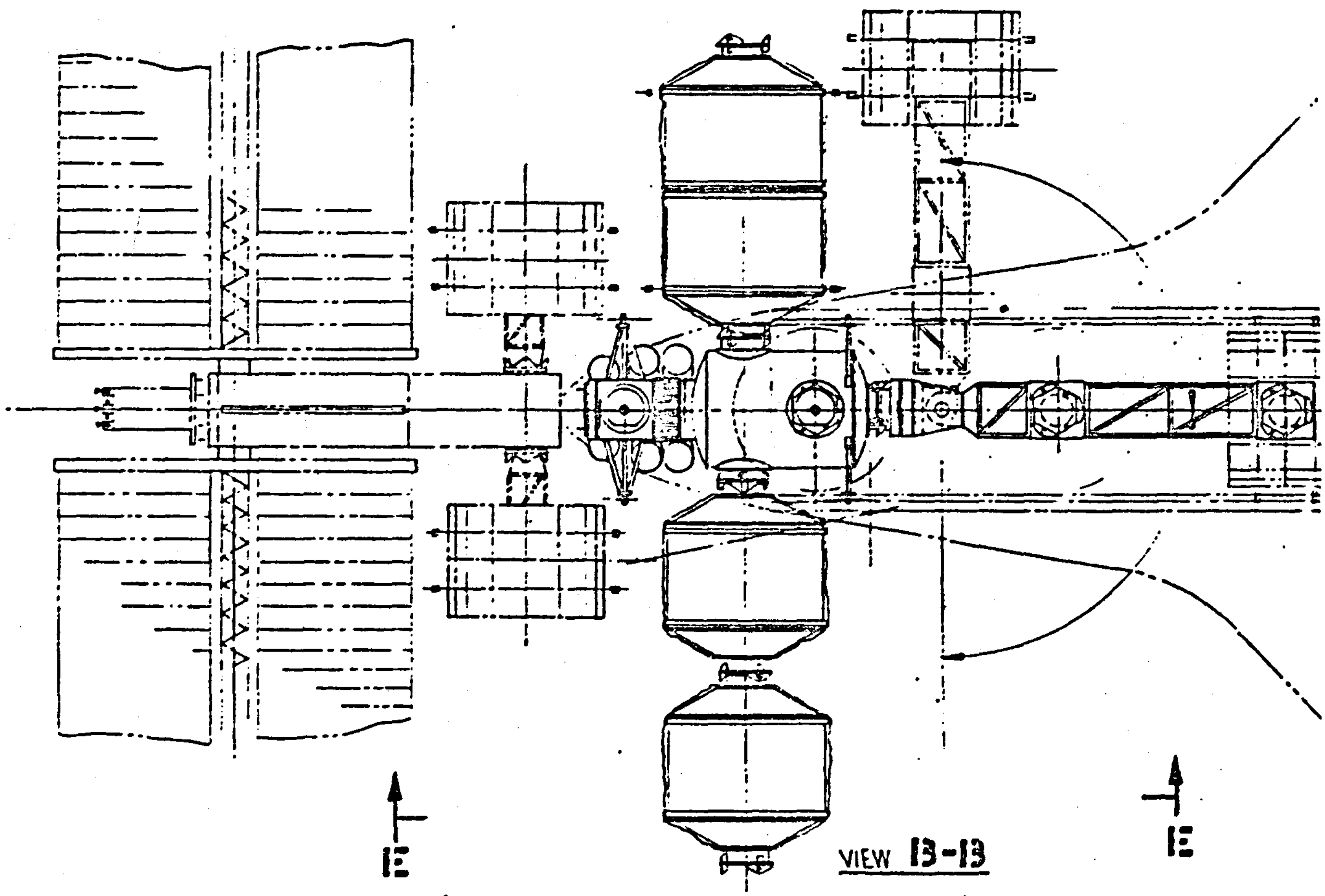

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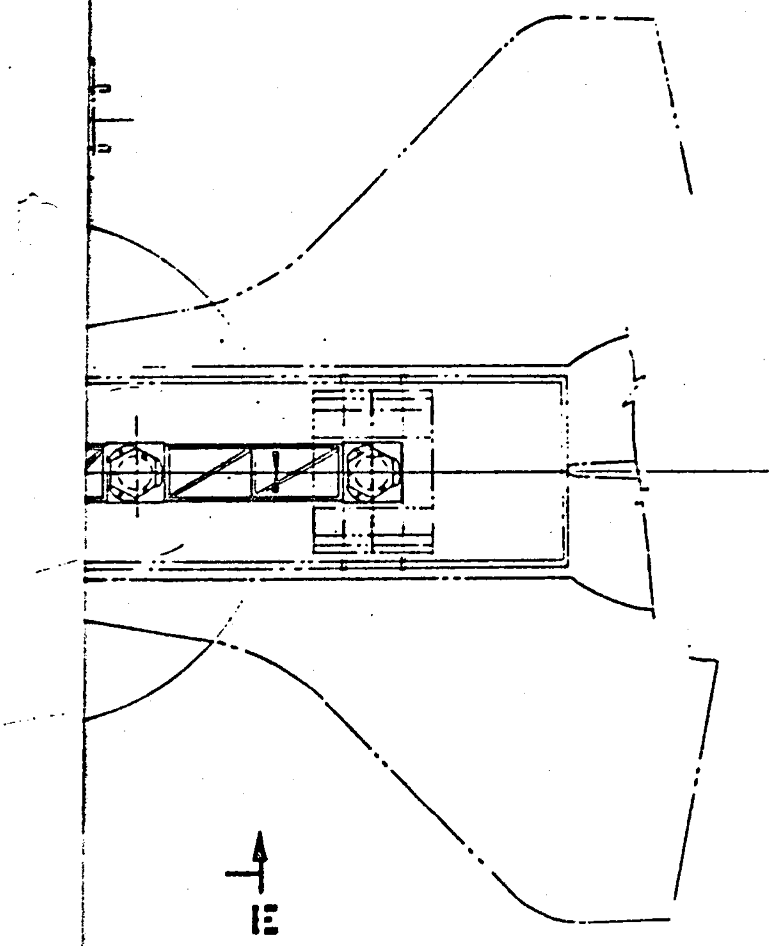

FIGURE 4.3.2.2-2/2

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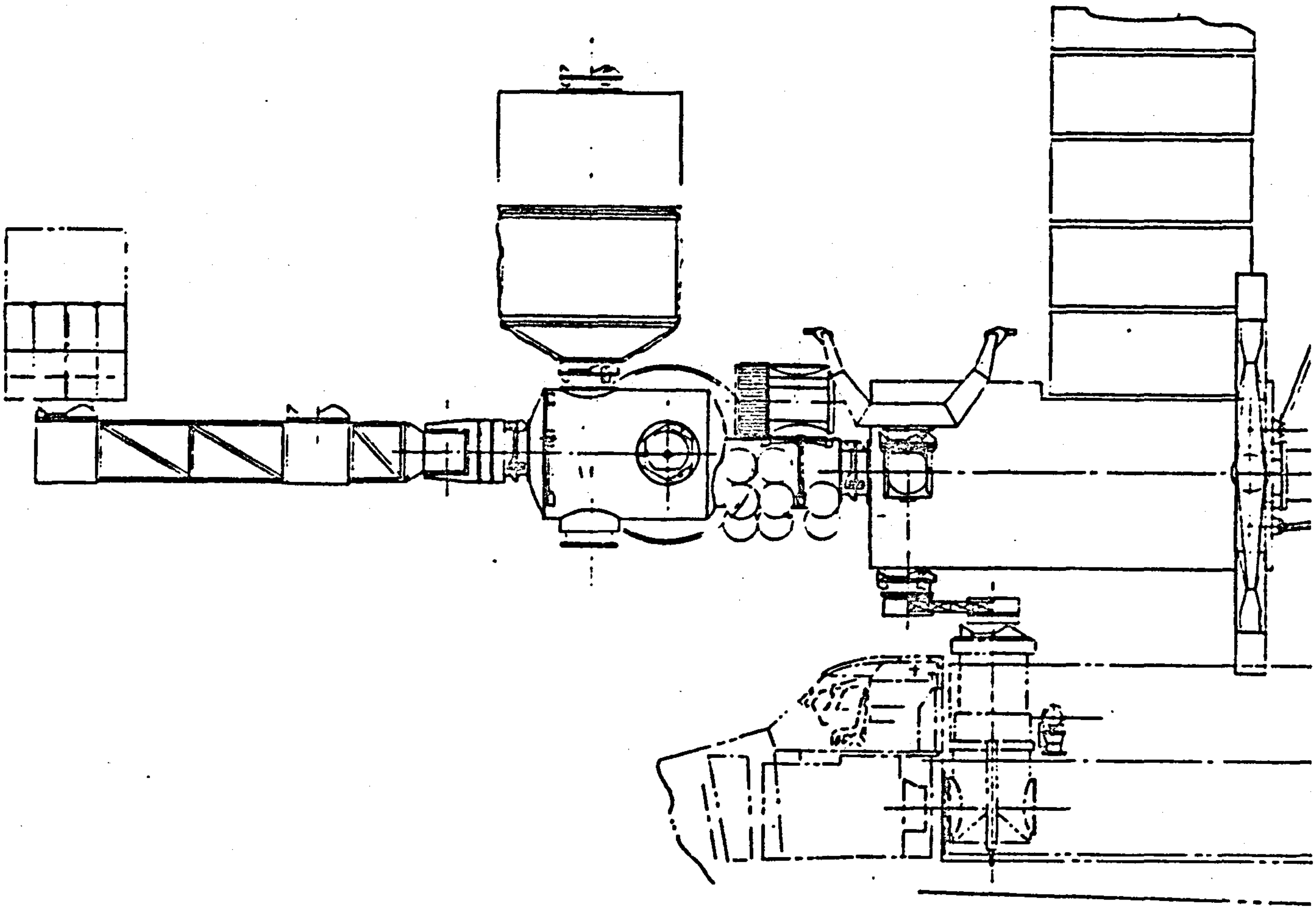

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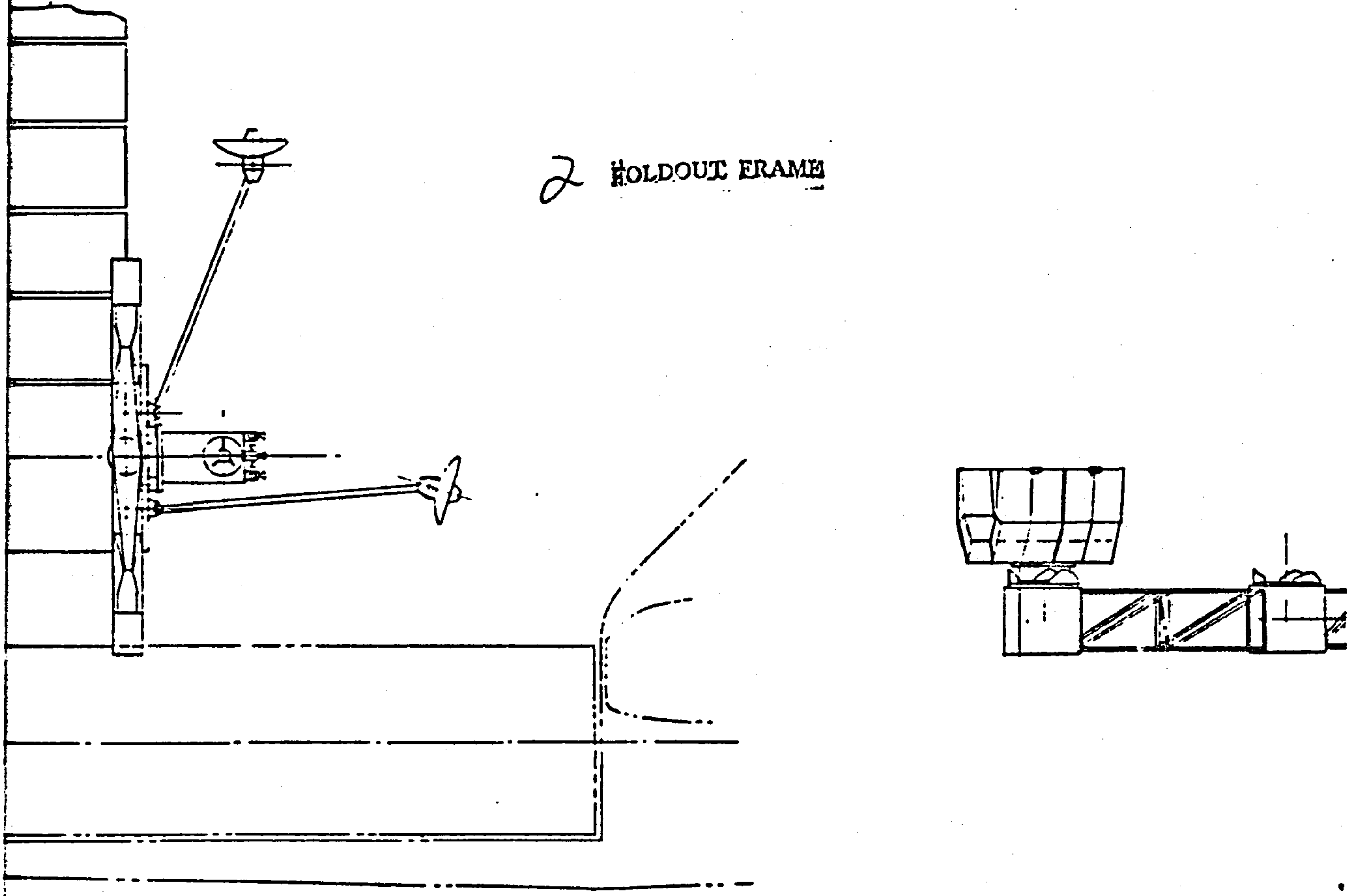

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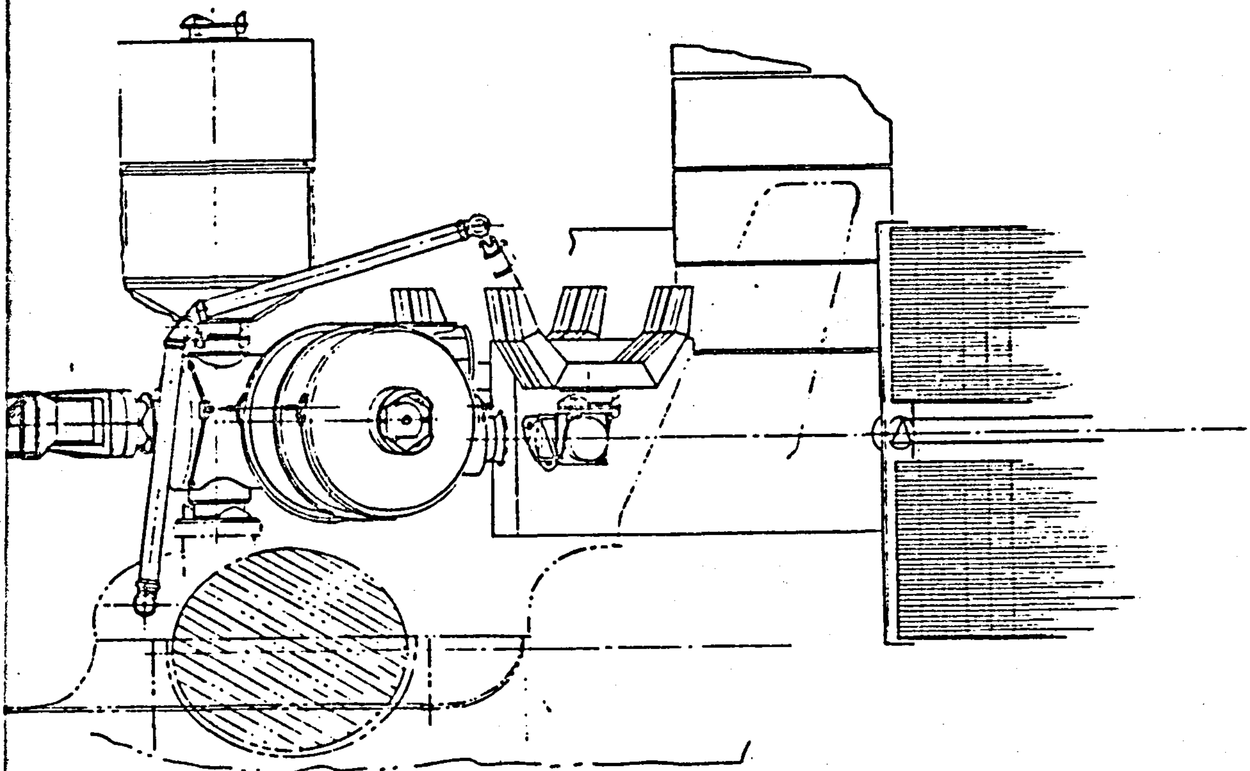

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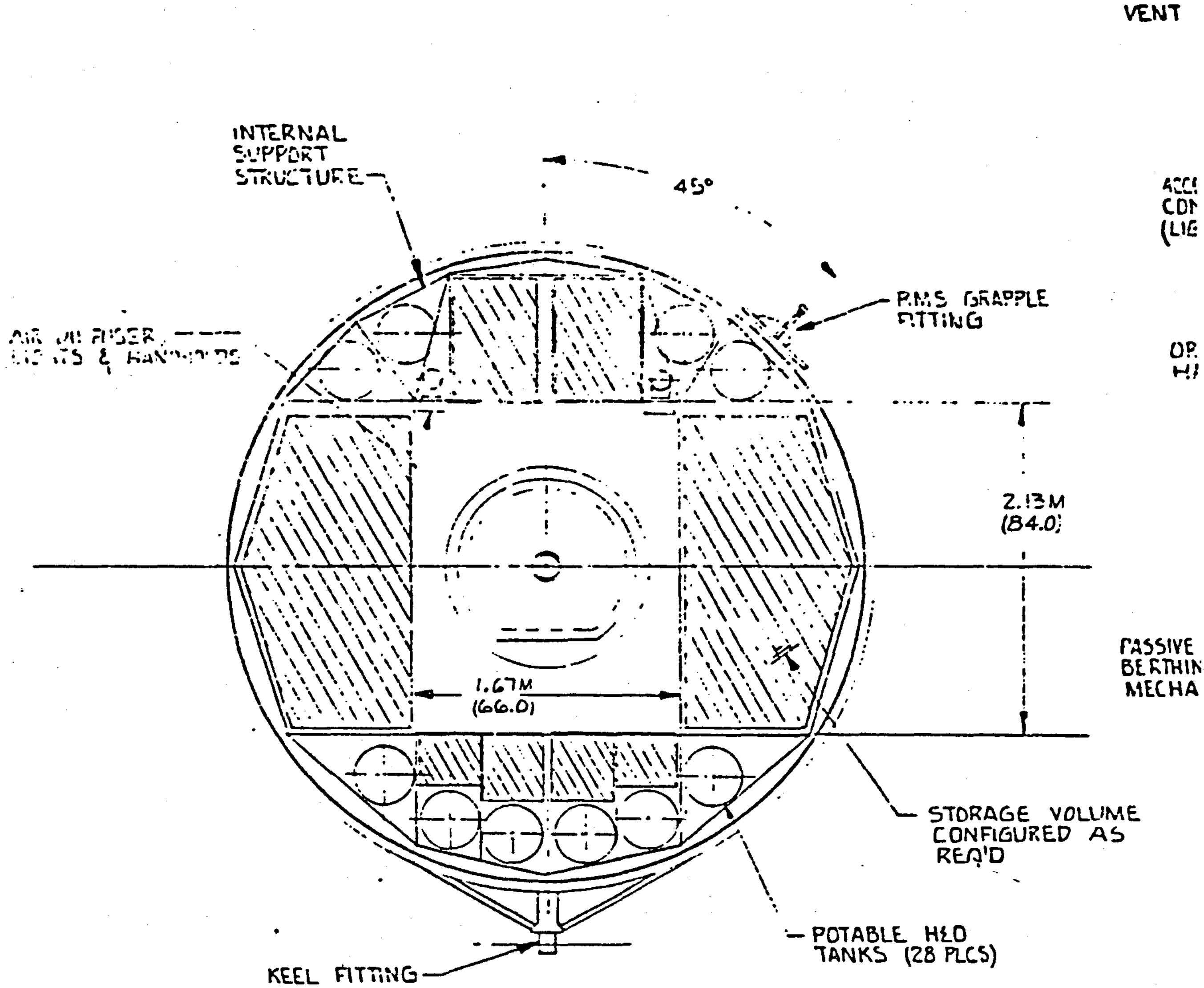

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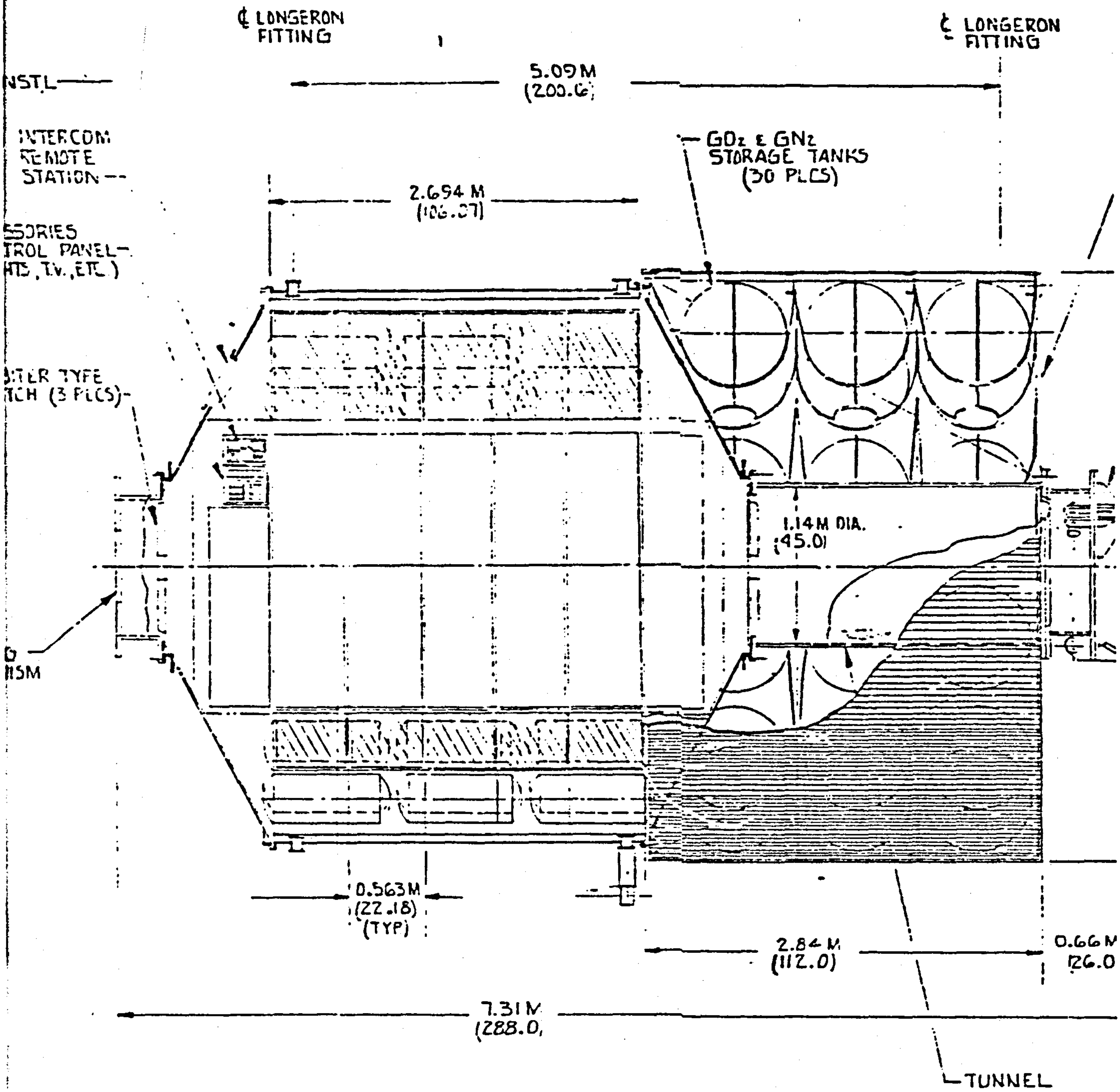

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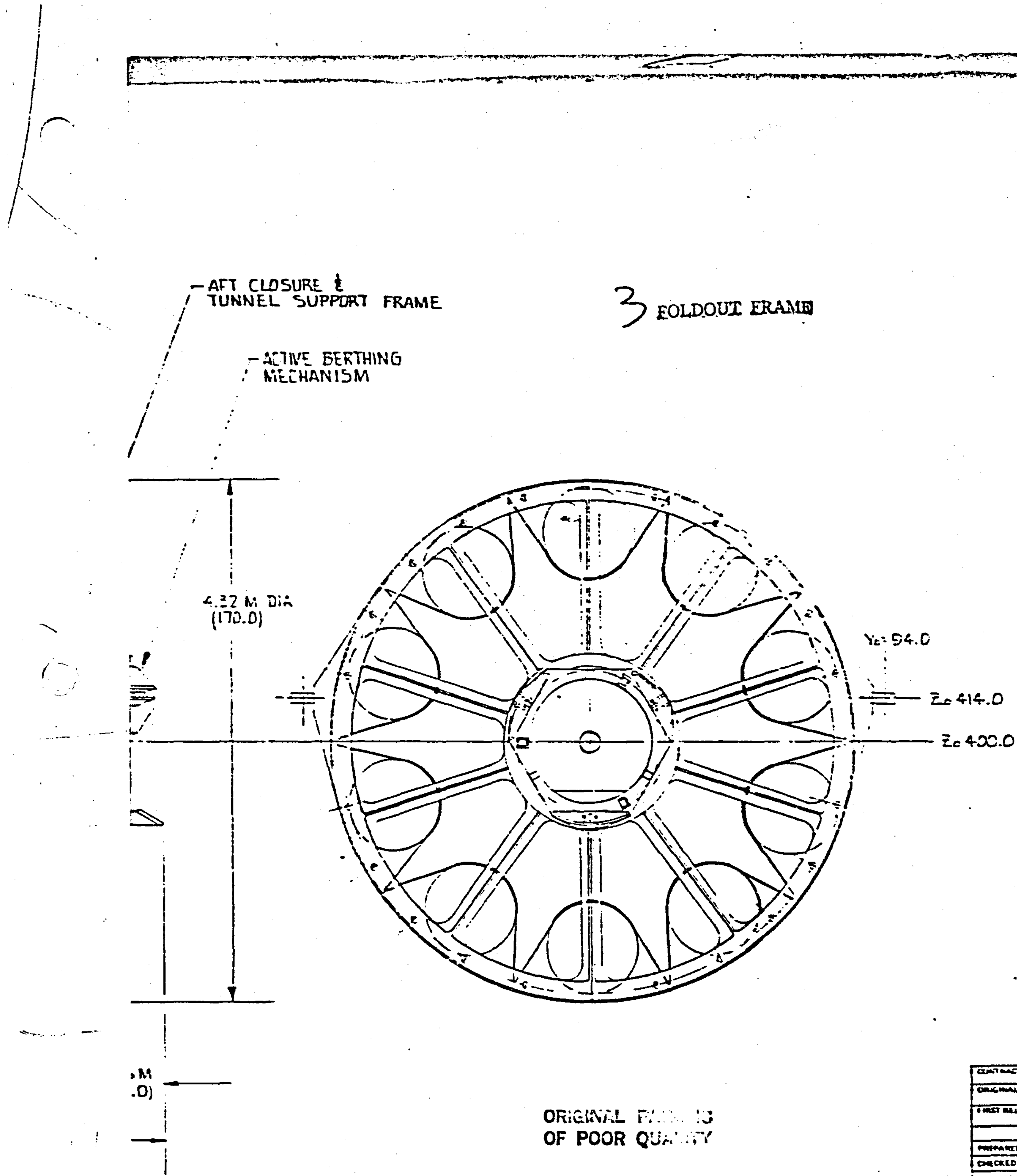

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